MINIMUM STANDARD 3.11

BIORETENTION BASIN PRACTICES

3.11A **Bioretention Filters**

3.11B **Green Alleys**

View BMP Images

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS Contd.

MINIMUM STANDARD 3.11

BIORETENTION BASINS

Definition

Bioretention is an innovative BMP developed by the Prince George's County, Maryland Department of Environmental protection. The following information is drawn from their ***Design Manual for Use of Bioretention in Stormwater Management*** (P.G. County, 1993) unless otherwise noted. This technology is also referred to as "Rain Gardens."

Figure 3.11-1 illustrates the Maryland bioretention (Rain Garden) concept as adapted for use in Virginia. There are seven major components to the bioretention area (Rain Garden): 1) the grass buffer strip; 2) the ponding area; 3) the surface mulch and planting soil; 4) the sand bed (optional); 5) the organic layer; 6) the plant material, and 7) the infiltration chambers. Each component is critical to sustaining a properly functioning BMP.

Purpose

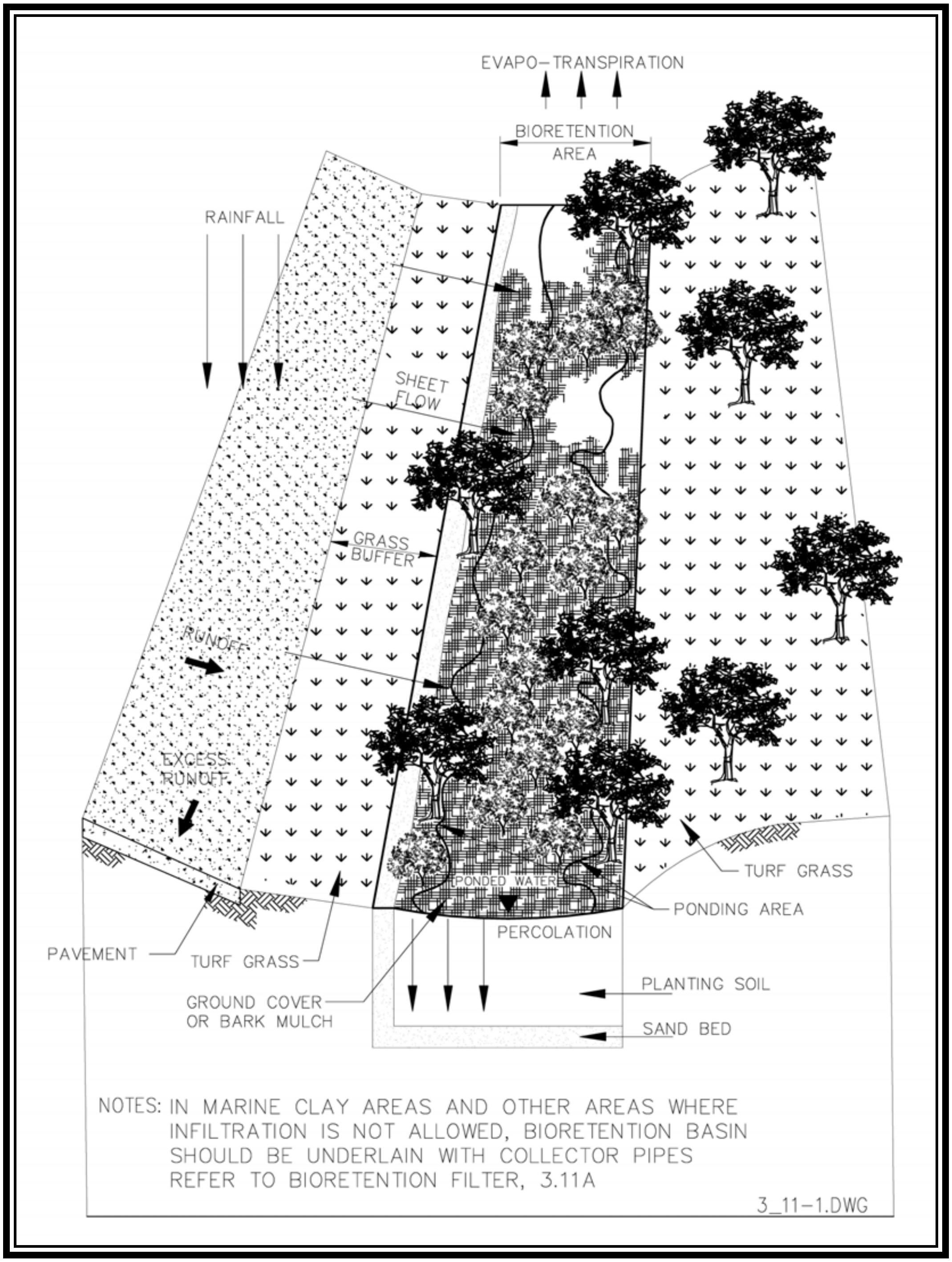
Bioretention basins are used primarily for water quality control. However, since they capture and infilter part of the stormwater from the drainage shed, they may provide partial or complete control of streambank erosion and partial protection from flooding (depending on the volume of water being captured and infiltered).

Bioretention facilities (Rain Gardens) are planting areas installed in shallow basins in which the stormwater runoff is treated by filtering through the bed components, biological and biochemical reactions within the soil matrix and around the root zones of the plants, and infiltration into the underlying soil strata. Properly constructed bioretention areas replicate the ecosystem of an upland forest floor through the use of specific shrubs, trees, ground covers, mulches and deep, rich soils. Since almost all bioretention basins are intended to be visual landscape amenities as well as stormwater BMPs, aesthetic considerations may be equally as important in their use as proper engineering. Bioretention design requires participation by a person with appropriate design skills and a working knowledge of indigenous horticultural practices, preferably a Landscape Architect.

<u>Water Quality Enhancement</u>

Bioretention basins enhance the quality of stormwater runoff through the processes of adsorption, filtration, volitization, ion exchange, microbial and decomposition prior to exfiltration into the surrounding soil mass. Microbial soil processes, evapotranspiration, and nutrient uptake in plants also come into play (Bitter and Bowers, 1995).

FIGURE 3.11 - 1
Bioretention Basin



The **grass buffer strip** filters particles from the runoff and reduces its velocity. The **sand bed** further slows the velocity of the runoff, spreads the runoff over the basin, filters part of the water, provides for positive drainage to prevent anaerobic conditions in the planting soil and enhances exfiltration from the basin. The **ponding area** functions as storage of runoff awaiting treatment and as a presettling basin for particulates that have not been filtered out by the grass buffer. The **organic or mulch layer** acts as a filter for pollutants in the runoff, protects the soil from eroding , and provides an environment for microorganisms to degrade petroleum-based solvents and other pollutants. The **planting soil layer** nurtures the plants with stored water and nutrients. Clay particles in the soil adsorb heavy metals, nutrients, hydrocarbons, and other pollutants. The **plant species** are selected based on their documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer (*ibid*). By providing a variety of plants, monoculture susceptibilities to insect and disease infestation are avoided, and evapotranspiration is enhanced. The **vented infiltration chambers** provide unobstructed exfiltration through the open-bottomed cavities, decrease the ponding time above the basin, and aerate the filter media between storms through the open chamber cavities and vents to grade, preventing the development of anaerobic conditions. By providing a valve equipped drawdown drain to daylight, the basin can be converted into a soil media filter should exfiltration surface failures occur.

Perforated underdrain systems are recommended for facilities placed in residential areas and in all areas where the in-situ soils are questionable. Refer to **3.11A - Bioretention Filter**.

The minimum width for a bioretention area is usually 10 feet, although widths as narrow as 4 feet may be used if the runoff arrives as dispersed sheet flow along the length of the facility from a properly sized vegetated strip. The minimum length should be 15 feet (for lengths greater than 20 feet, the length should be at least twice the width to allow dispersed sheet flow). As an infiltration BMP, the maximum ponding depth is restricted to six inches to restrict maximum ponding time to preclude development of anaerobic conditions in the planting soil (which will kill the plants) and to prevent the breeding of mosquitoes and other undesirable insects in the ponded water. The planting soil must have sufficient depth to provide appropriate moisture capacity, create space for the root systems, and provide resistance from windthrow (Minimum depth equal to the diameter of the largest plant root ball plus 4 inches).

Table 3.11-1 contains the target removal efficiencies once a **mature** plant community is created in the bioretention areas based on the volume of runoff to be captured and infiltered.

Flood Control and Channel Erosion

The amount of flood and channel erosion control provided by bioretention basins depends on the local rainfall frequency spectrum, the amount of pre-development (or pre-redevelopment) impervious cover, the amount of post-development impervious cover, and the volume of runoff captured and infiltered by the basin(s). The effect of the BMPs on peak flow rates from the drainage shed must be examined. As with other infiltration practices, bioretention basins tend to reverse the consequences of urban development by reducing peak flow rates and providing groundwater discharge.

TABLE 3.11-1
Pollutant Removal Efficiencies for Bioretention Basins

BMP Description	Target Phosphorus Removal Efficiency
Bioretention basin with capture and treatment volume equal to 0.5 inches of runoff from the impervious area.	50%
Bioretention basin with capture and treatment volume equal to 1.0 inches of runoff from the impervious area.	65%

Conditions Where Practice Applies

Bioretention basins are suitable for use on any project where the subsoil is sufficiently permeable to provide a reasonable rate of infiltration and where the water table is sufficiently lower than the design depth of the facility to prevent pollution of the groundwater. Bioretention basins are generally suited for almost all types of development, from single-family residential to fairly high density commercial projects. They are attractive for higher density projects because of their relatively high removal efficiency. **Figures 3.11-2** through **3.11- 5** illustrate several applications. Bioretention basins may also be installed in off-line pockets along the drainage swales adjacent to highways or other linear projects, as illustrated in **Figure 3.11-6**. For large applications, several bioretention basins connected by an underground infiltration trench ("Green Alleys") are preferable to a single, massive basin. Such a system is especially desirable along the landward boundary of reduced Chesapeake Bay Resource Protection Areas. **Minimum Standard 3.11B** discusses this system. Considering the character of bioretention basins, some jurisdictions may qualify them as buffer restoration.

FIGURE 3.11 - 2
Bioretention Basin at Edge of Parking Lot With Curb

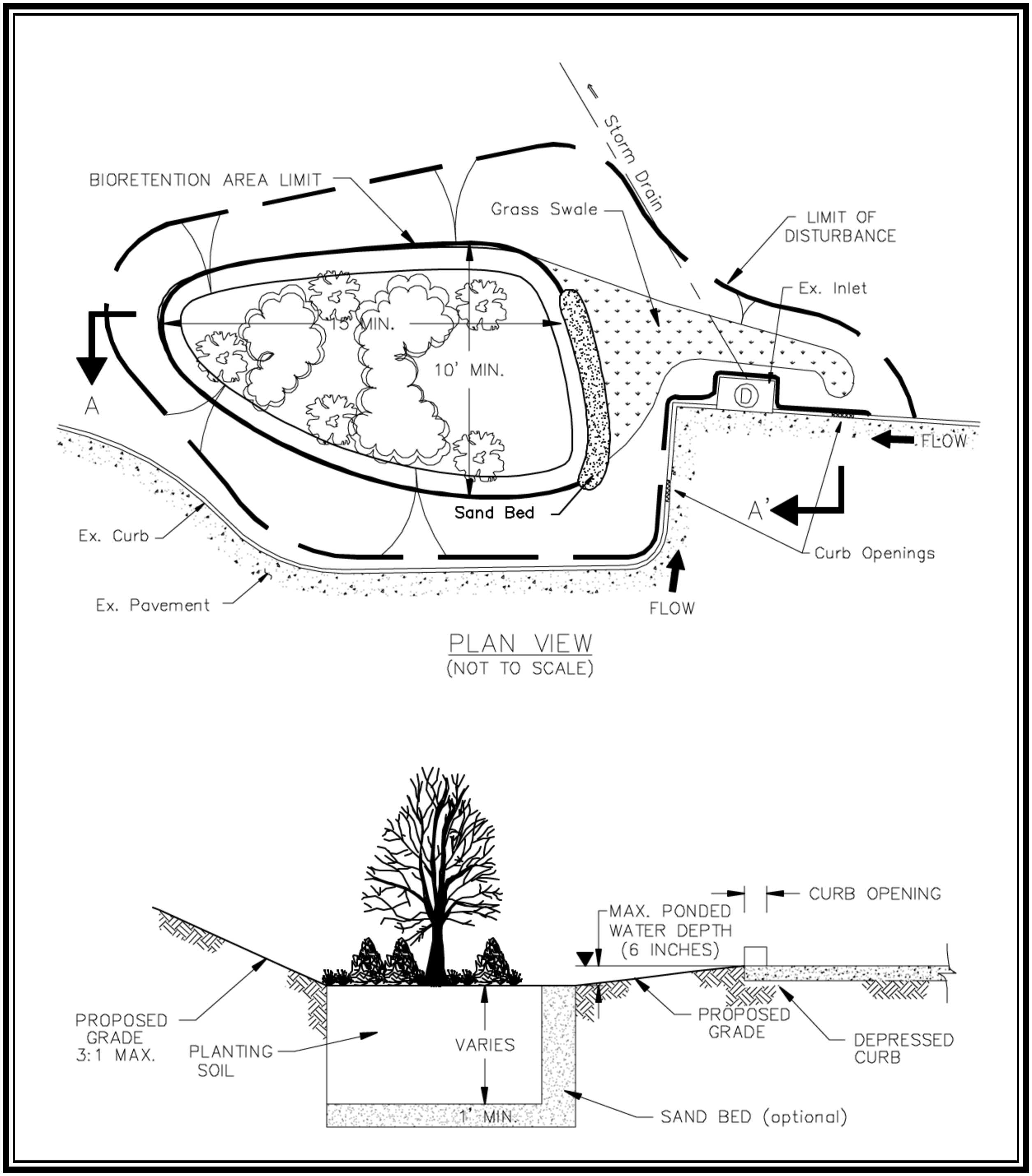


FIGURE 3.11 - 3
Bioretention Basin in a Planting Island in a Parking Lot

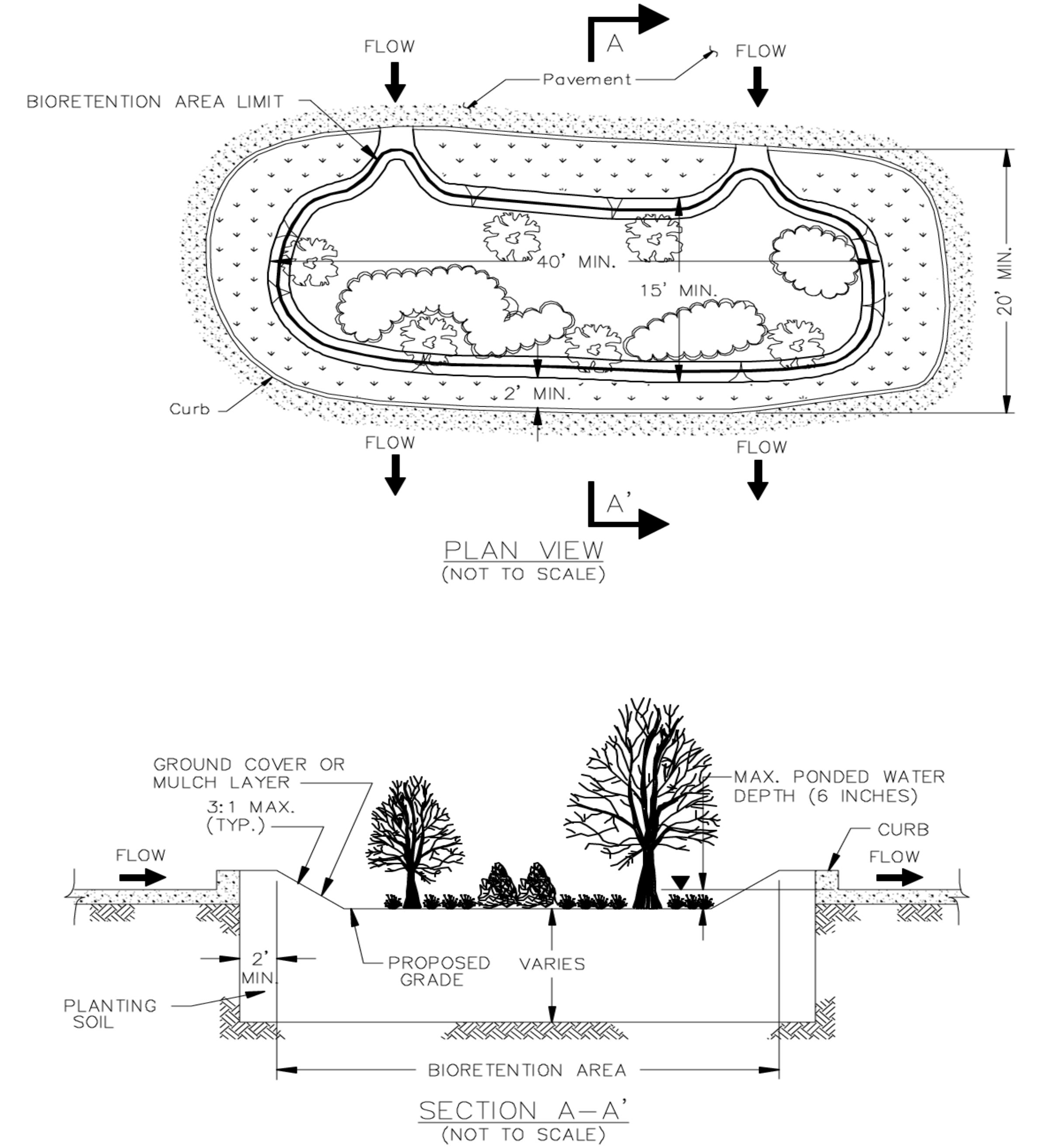


FIGURE 3.11-4
Bioretention Basin Adjacent to a Drainage Swale

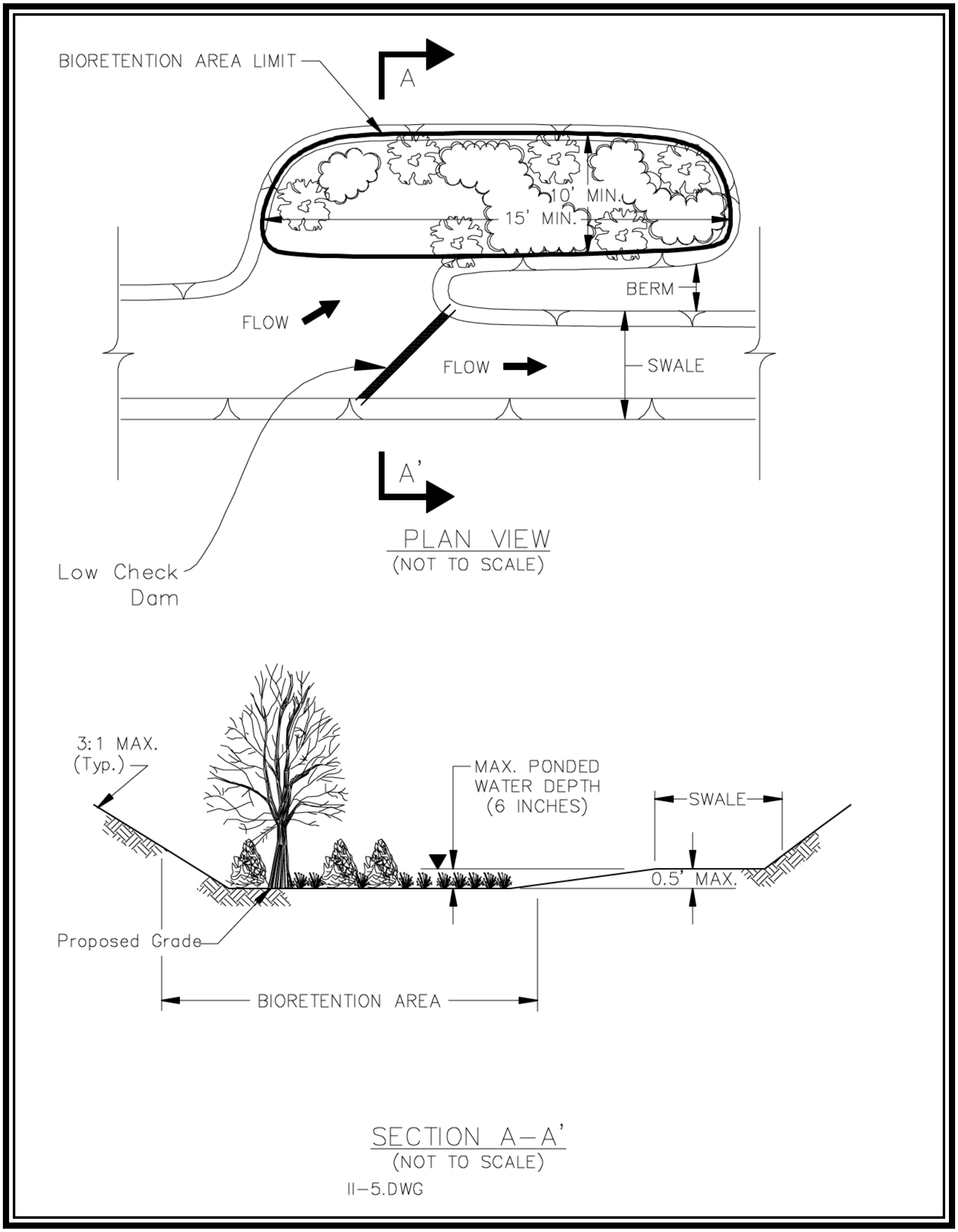
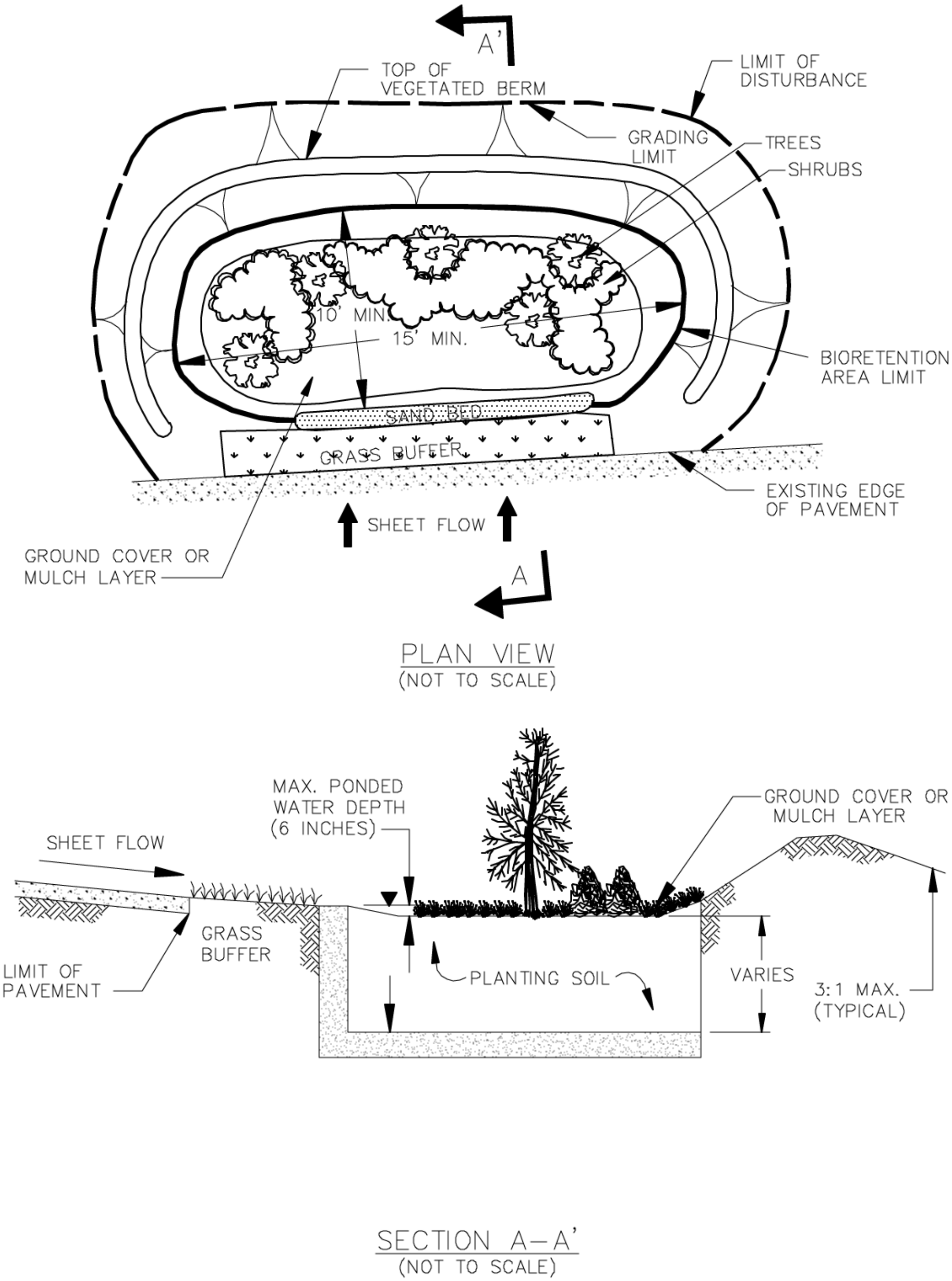


FIGURE 3.11-5
Bioretention Basin at Edge of Parking Lot Without Curbs



Planning Considerations

Site Conditions

All of the Site Conditions considerations for general infiltration practices contained in **MINIMUM STANDARD 3.10** also apply to bioretention basins. Designers should also be mindful of local requirements for soil studies for infiltration practices such as those in the ***Northern Virginia BMP Handbook***. In addition to site conditions affecting infiltration practices in general, the following apply specifically to bioretention basins. The application of individual bioretention basins will usually be limited to drainage areas from 0.25 to 1 acre. Generally, commercial or residential drainage areas exceeding 1 acre in size will discharge sheet flows greater than 5 cfs.

1. Location Guidelines

Preferable locations for bioretention basins include 1) areas upland from inlets or outfalls that receive sheet flow from graded areas, and 2) areas of the site that will be excavated or cut. When available, areas of loamy sand soils should be used since these types of soils comprise the planting soils for bioretention basins. Locating the BMP in such natural locations would eliminate the cost of importing planting soils (see soil and organic specification under **Design Considerations**). BMP location should be integral with preliminary planning studies.

The following areas would be **undesirable** for bioretention basins: 1) areas that have mature trees which would have to be removed for construction of the bioretention basin, 2) areas that have existing slopes of 20% or greater, and 3) areas above or inclose proximity to an unstable soil strata such as marine clay.

2. Sizing Guidelines

For planning purposes, assume that the floor area of the bioretention basin will be a minimum of 2.5% of the impervious area draining to the basin if the first 0.5 inches of runoff is to be treated and a minimum of 4.0% of the impervious area on the drainage shed if the first 1.0 inches of runoff is to be treated. Derivation of these values is discussed below under **Design Considerations**. Note that small projects such as single family residences will likely default to the minimum 150 square foot area (10' X 15').

3. Aesthetic Considerations

Aesthetic considerations of the bioretention basin must be considered early in the site planning process. While topography and hydraulic considerations may dictate the general placement of such facilities, overall aesthetics of the site and the bioretention basins must be integrated into the site plan and stormwater concept plan from their inception. Both the stormwater engineer and the Landscape Architect must participate during the layout of facilities and infrastructure to be placed on the site. Bioretention design must be an integral part of the site planning process.

Sediment Control

Like other infiltration practices, provisions for long-term sediment control must be incorporated into the design, **as well as precautions during on-site construction activities.** Careful consideration must be given **in advance of construction** to the effects of work sequencing, techniques, and equipment employed on the future maintenance of the practice. Serious maintenance problems can be averted, or in large part, mitigated, by the adoption of relatively simple measures during construction.

1. Construction Runoff

Bioretention basin BMPs should be constructed AFTER the site work is complete and stabilization measures have been implemented. If this is not possible, strict implementation of E&S protective measures must be installed and maintained in order to protect the bioretention facility from premature clogging and failure.

Like other infiltration BMPs, bioretention basins constructed prior to full site stabilization will become choked with sediment from upland construction operations, rendering them inoperable from the outset. Simply providing inlet protection or some other filtering mechanism during construction will not adequately control the sediment. One large storm may completely clog the bioretention basin, requiring complete **reconstruction**.

Experience with infiltration practices has also demonstrated that the bioretention basin site should **NOT** be used as the site of sedimentation basins during construction. Such use tends to clog the underlying strata and diminish their capacity to accept infiltration below that indicated in preconstruction soil studies.

Bioretention basins are landscape amenities and should be installed with other landscaping as the last stage of project construction.

A detailed sediment control design to protect the bioretention basin **during** its construction should be included with the facility design. The ***Virginia Erosion and Control Handbook*** (VDCR, 1992), ***Standards and Specifications for infiltration Practices*** (Md. DNR, 1984), and ***Controlling Urban Runoff*** (MWCOG, 1987) provide technical guidance on sediment control designs.

Experience with bioretention basins in Maryland has demonstrated that they must be protected until the drainage areas contributing to the practice have been adequately stabilized (P.G. Co., 1993).

The definition of the term "adequately stabilized" is critical to the success of the facility. At the conclusion of construction activity, the temporary erosion and sediment control measures are usually removed at the direction of the erosion and sediment control inspector when, at a minimum, stabilization measures such as seed and mulch are in place. This does not mean, however, that stabilization has actually occurred. Bioretention basins must be protected until stabilization of the upland site is functioning to control the sediment load from denuded areas. Provisions to bypass the stormwater away from the bioretention basin during the stabilization period should be implemented.

2. Urban Runoff

A fully stabilized site will generate particulate pollutant load resulting from natural erosion, lawn and garden debris such as leaves, grass clippings, mulch, roadway sand, etc. Pretreatment of runoff to remove sediments prior to entering the bioretention basin is usually provided by a grass filter strip or grass channel. When runoff from sheet flow from such areas as parking lots, residential yards, etc., is involved, a grass filter strip, often enhanced with a pea gravel diaphragm, is usually employed. **Table 3.11-2** provides sizing guidelines as a function of inflow approach length, land use, and slope. The minimum filter strip length (flow path) should be 10 feet.

TABLE 3.11-2
Pretreatment Filter Strip Sizing Guidance
(Source: Claytor and Schueler, 1996)

Parameter	Impervious Parking Lots				Residential Lawns				Notes
Maximum Inflow Approach Length (feet)	35		75		75		150		
Filter Strip Slope	≤ 2%	≥2%	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum = 6%
Filter Strip Minimum Length	10'	15'	20'	25'	10'	12'	15'	18'	

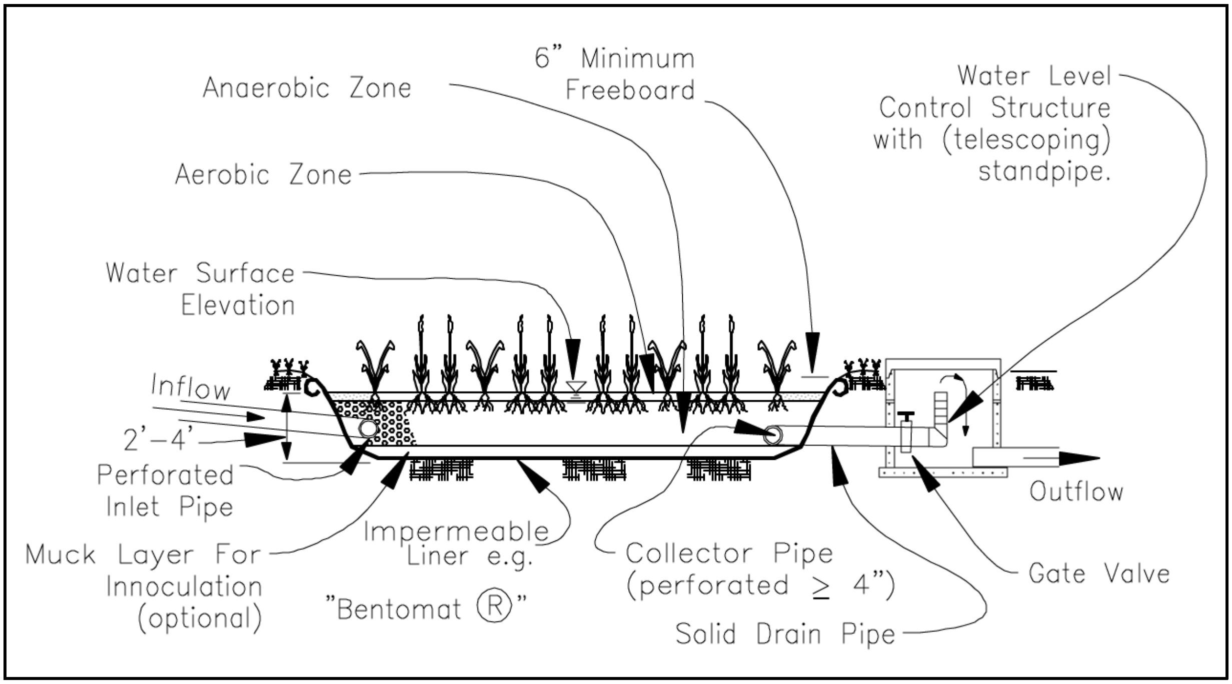
For applications where concentrated runoff enters the bioretention basin by surface flow, such as through a slotted curb opening, a grassed channel, often equipped with a pea gravel diaphragm to slow the velocity and spread out the flow entering the basin, is the usual pretreatment method. The length of the grassed channel depends on the drainage area, land use, and channel slope. **Table 3.11-3** provides recommendations on sizing for grass channels leading into a bioretention basin for a one acre drainage area. The minimum grassed channel length should be 20 feet.

"Grassed filter strips, grassed channels, and side-slopes of the basin should be **sodded with mature sod** prior to placement of the bioretention basin into operation. Simply seeding these areas will likely result in conveyance of sediments into the basin and premature failure. Wrapping of the planting soil mixture up the side slopes beneath the sod is also recommended."

TABLE 3.11-3
Pretreatment Grass Channel Sizing Guidance for a 1.0-Acre Drainage Area
(Source: Claytor and Schueler, 1996)

Parameter	**≤ 33% Impervious**		**Between 34% and 66% Impervious**		**≥ 67% Impervious**		**Notes**
Slope	≤2%	≥2%	≤2%	≥2%	≤2%	≥2%	Maximum slope = 4%
Grassed channel minimum length (feet)	25	40	30	45	35	50	Assumes a 2' wide bottom width

FIGURE 3.11-6
Upflow Inlet for Bioretention Basin
(Source: City of Alexandria)



When concentrated piped flow from impervious areas such as parking lots is routed to a bioretention basin, an energy absorbing and sedimentation structure in which the flow rises into the basin like a tide is usually advisable. Since sediments must usually be removed from such structures on a regular basis, they must be placed in locations where the extension booms on vacuum trucks may easily reach them. **Figure 3.11-6** illustrates an upflow inlet structure for a bioretention basin. Maintenance requirements for pretreatment measures are discussed **Maintenance/Inspection Guidelines**.

General Design Criteria

The purpose of this section is to provide minimum criteria for the design of bioretention basin BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements. Bioretention basins which capture and infilter the first 1 inch of runoff from impervious surfaces may also provide streambank erosion protection.

General

The design of bioretention basins should be in accordance with the following Minimum Standards where applicable: **3.1: Earthen Embankments, 3.2: Principal Spillways, 3.3: Vegetated Emergency Spillways, 3.4: Sediment Forebay, 3.10: General Infiltration Practices, and 3.10A: Infiltration Basin,** as well as the additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for the particular design but also for ensuring long-term operation.

Soils Investigation

Refer to the **Planning Considerations** and **Design Criteria** of **General Infiltration Practices, MS-3.10**, and to local jurisdiction soil study requirements such as Chapter 5, Section V. of the ***Northern Virginia BMP Handbook***. As with infiltration basins (**MS3.10A**), a minimum of one soil boring log should be required for each 5,000 square feet of bioretention basin area (plan view area) and in no case less than three soil boring logs per basin.

Topographic Conditions

Like other infiltration facilities, bioretention basins should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the impact of the basin upon the steep slope (especially in marine clay areas). Also, bioretention basins should be a minimum of 100 feet up-slope and 20 feet downslope from any buildings.

Basin Sizing Methodology

In Virginia, bioretention basins are designed to exfilter the treatment quantity into the underlying soil strata, or into an underlying perforated underdrain system connected to a storm drain system or other outfall when the underlying soils, proximity to building foundation, or other such restrictions preclude the use of infiltration. When such an underdrain system is used, the facility is referred to as a **Bioretention Filter - Minimum Standard 3.11A**.

Recent research at the University of Maryland has supported a reduction in overall depth of the planting soil to 2.5 feet. Generally, the soil depth can be designed to a minimum depth equal to the diameter of the largest plant root ball plus 4 inches. The recommended soil composition was revised to reduce the clay and increase the sand content (Refer to Soil Texture and Structure later in this standard). This revised soil composition also eliminated the 12" sand layer at the bottom of the facility. The researchers concluded that significant pollutant reductions are achieved in the mulch layer and the first 2 to 2.5 feet of soil.

The elevation of the overflow structure should be 0.5 feet above the mulch layer of the bioretention bed. When an underdrain system is used (Min. Std. 3.11A), the overflow can be as much as 1.0 feet above the mulch layer.

The size of the bioretention facility is dictated by the amount of impervious surface in the contributing drainage area. For facilities capturing the first 0.5 inches of runoff from the impervious areas in the drainage shed, the surface area of the bioretention bed should be a minimum of 2.5% of the impervious area, or 1,090 square feet per impervious acre. For facilities capturing the first 1.0 inch of runoff, the bioretention bed should be a minimum of 5.0% of the impervious area, or 2,180 square feet per impervious acre.

The minimum width and length is recommended at 10 feet and 15 feet respectively. (Widths as narrow as 4 feet may be used if the runoff arrives as dispersed sheet flow along the length of the facility from a properly sized vegetated strip).

The elevation of the overflow structure should be 0.5 feet above the mulch elevation of the bioretention bed.

Note that small projects such as single family residences may default to the minimum (10' X 15') 150 square foot area.

TABLE 3.11-4
Basin Sizing Summary

Treatment Volume	**Basin Surface Area** (Expressed as percentage of impervious area)
0.5" per impervious acre	2.5%
1.0" per impervious acre	5.0%

<u>Runoff Pretreatment</u>

Like other infiltration basins, bioretention basins must always be preceded by a pretreatment facility to remove grease, oil, floatable organic material, and settleable solids (see Urban Runoff section of **Sediment Control** under **Planning Considerations** above). Where space constraints allow, runoff should be filtered by a grass buffer strip and sand bed. The buffer strip and sand bed will reduce the amount of fine material entering the bioretention area and minimize the potential for clogging of the planting soil. The sand bed also increases the infiltration capacity and provides aeration for the plant roots in the bioretention area. For basins for which high sediment loadings are expected (treating largely pervious areas, etc.), the design can be modified to include a sediment forebay (see **MS 3.04**). Any pretreatment facility should be included in the design of the basin and should include maintenance and inspection requirements.

Drainage Considerations

The grading design must shape the site so that all runoff from impervious areas is routed through the bioretention basins. The basins must be sited so as to accept the design runoff quantity before bypassing any excess flow to the storm drainage system. Bioretention basin locations must therefore be integrated into the basic site design from its inception. Most of the **Planning Considerations** delineated above must come into play at this early stage in the design process. The overall site and impervious surfaces must be contoured to direct the runoff to the basins. **Bioretention basins cannot usually be successfully integrated into a site design that does not take stormwater management into account from its inception.** Elevations must be carefully worked out to assure that the desired amount runoff will flow into the basins and pool at no more that the maximum design depth. This requires a much higher degree of vertical control during construction that is normal with most landscaping work.

Preferably, bioretention basins should be placed “off-line,” i.e. the design should provide for runoff to be diverted into the basin until it fills with the treatment volume and then bypass the remaining flow around the BMP to the storm drainage system. The drainage system is normally designed to handle a specific storm event (the 10-year storm in most of Virginia). To prevent flood damage , however, the bioretention basin design must take into account how the runoff will be processed when larger events occur. This may require, at a minimum, that a vegetated emergency spillway be provided (see **MS-3.03**), and that a path for overland flow to an acceptable channel be incorporated into the design. The designer should provide for relief from the storm event specified by local development approval authority or for the 25-year storm event, whichever is the most stringent.

Figure 3.11-2 illustrates an “off-line” application at the edge of a parking lot with curb and gutter. The inlet deflectors divert runoff into the bioretention basin until the basin fills and backs up. Subsequent runoff then bypasses to the adjacent, down gradient storm inlet. **Figure 3.11-3** illustrates an “off-line” application in a planting island in a parking lot, while **Figure 3.11-4** illustrates an “off-line application adjacent to a drainage swale (such highway drainage). Again, runoff flows into the bioretention basin until it fills, then bypasses down the swale. Placement of a flow diversion check dam in the swale will facilitate filling the basin. In some situations, an “off-line” configuration may not be practical or economical. Figure **3.11-1** and **3.11-5** illustrate applications where sheet flow enters the bioretention basin.

Figure 3.11-7 illustrates a grading plan for a bioretention basin. The grading plan was created for a double-cell bioretention area. There is a seven-foot buffer between cells which allow for the planting of upland trees. As indicated in the grading plan, sheet and gutter flow is diverted into the bioretention areas through openings in the curb. The elevation of the invert of the bioretention area is set by the curb opening elevation. The curb opening elevation is 0.5 ft. higher than the invert of the bioretention area, so water is allowed to pond to a maximum depth of one-half foot before runoff bypasses the bioretention area and flows into the storm drain system.

Precise grading of the basin is critical to capturing the water quality volume and operation of the facility. The plan should have a contour interval of no more than one-foot, and spot elevations should be shown throughout the basin. The perimeter contour elevation should contain the design storm without over topping anywhere except at the outflow structure.

Exclusion of Continuous Flows and Chlorinated Flows

Bioretention and bioretention filter BMPs will **NOT** function properly if subjected to continuous or frequent flows. The basic principles upon which they operate assume that the sand filter will dry out and reaerate between storms. If the sand is kept continually wet by such flows as basement sump pumps, anaerobic conditions will develop, creating a situation under which previously captured iron phosphates degrade, leading to **export** of phosphates rather than the intended high phosphorous removal (Bell, Stokes, Gavan, and Nguyen, 1995). Anaerobic conditions will also kill most of the plants in the basin, stopping the biochemical pollutant removal processes and negating the aesthetic landscaping amenity aspects. It is also essential to **exclude flows containing chlorine and other swimming pool and sauna chemicals** since these will kill the bacteria upon which the principle nitrogen removal mechanisms depend.

Continuous or frequent flows (such as basement sump pump discharges, cooling water, condensate water, artesian wells, etc.) and flows containing swimming pool and sauna chemicals MUST BE EXCLUDED from routing through bioretention or bioretention filter BMPs since such flows will cause the BMP to MALFUNCTION!

Planting Plan

Selection of plantings must include coordination with overall site planning and aesthetic considerations for designing the bioretention plant community. Tables listing suitable species of trees, shrubs, and ground cover are provided at the end of this section. This listing is not intended to be all-inclusive due to the continual introduction of new horticultural varieties ans species in the nursery industry.

1. Planting Concept

The use of plantings in bioretention areas is modeled from the properties of a terrestrial forest community ecosystem. The terrestrial forest community ecosystem is an upland community dominated by trees, typically with a mature canopy, having a distinct sub-canopy of understory trees, a shrub layer, and herbaceous layer. In addition, the terrestrial forest ecosystem typically has a well-developed soil horizon with an organic layer and a mesic moisture regime. A terrestrial forest community model for stormwater management was selected based upon a forest's documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer. These three elements are the major elements of the bioretention concept.

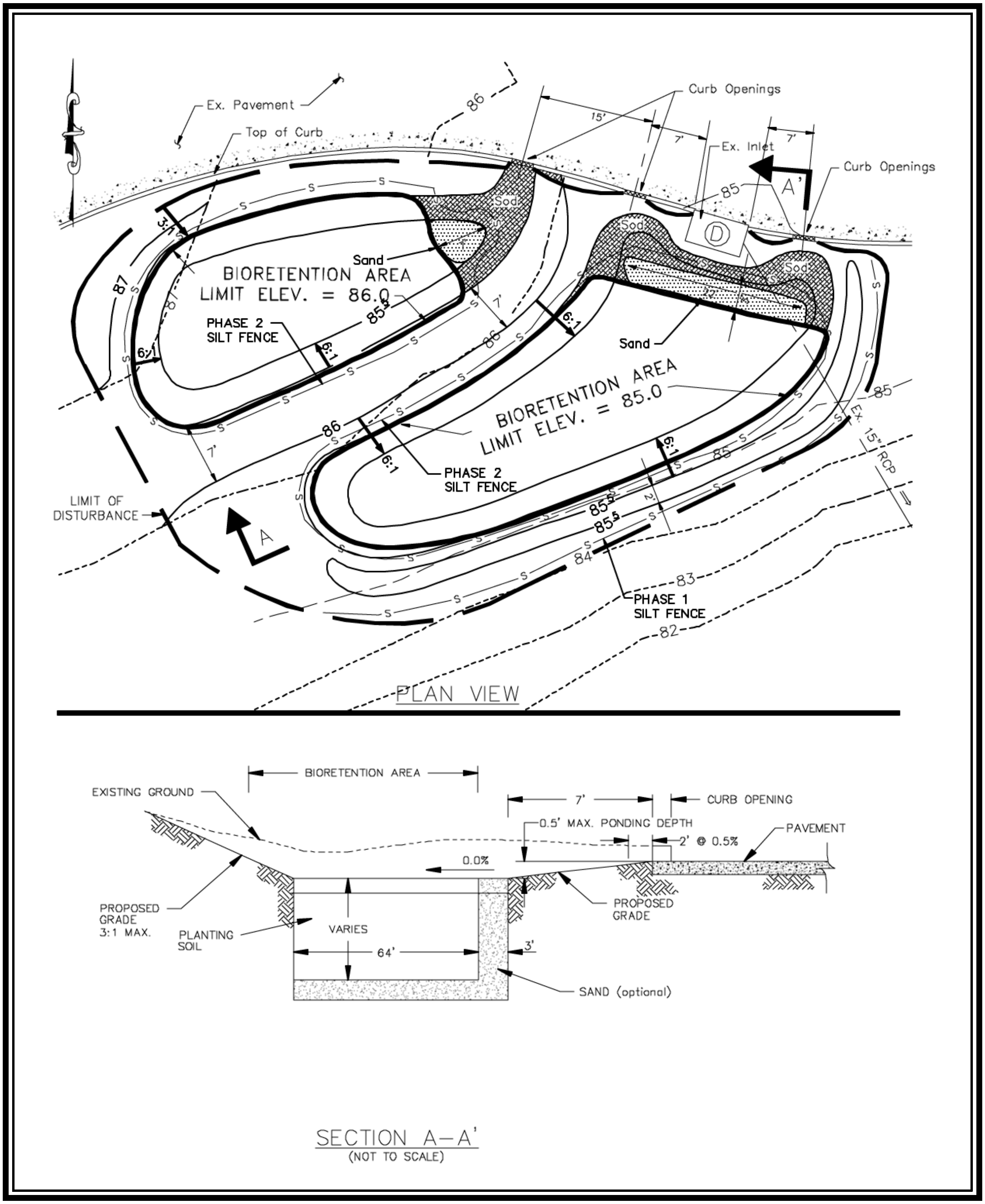
Key elements of the terrestrial forest ecosystem that have been incorporated into bioretention design include species diversity, density, and morphology, and use of native plant species. Species diversity protects the system against collapse from insect and disease infestations and other urban stresses such as temperature and exposure. Typically, indigenous plant species demonstrate a greater ability of adapting and tolerating physical, climatic, and biological stresses.

2. Plant Species Selection

Plant species appropriate for use in bioretention areas are presented in **Tables 3.11-7A** through **3.11-7C** , provided at the end of this section. These species have been selected based on the ability to tolerate urban stresses such as pollutants, variable soil moisture and ponding fluctuations. Important design considerations such as form, character, massing, texture, culture, growth habits/rates, maintenance requirements, hardiness, size, and type of root system are also included. A key factor in designating a species as suitable is its ability to tolerate the soil moisture regime and ponding fluctuations associated with bioretention. The plant indicator status (Reed, 1988) of listed species are predominantly facultative (i.e., they are adapted to stresses associated with both wet and dry conditions); however, facultative upland and wetland species have also been included. This is important because plants in bioretention areas will be exposed to varying levels of soil moisture and ponding throughout the year, ranging from high levels in the spring to potential drought conditions in the summer. All of the species listed in **Tables 3.11-7A - 3.11-7C** are commonly found growing in the Piedmont or Coastal Plain regions of Virginia as either native or ornamental species.

Recent research suggests an increase in the importance of the mulch layer and groundcover plant species in pollutant removal. The plant list in this standard will be expanded to include perennial flowering plants. A robust groundcover species with a thick mulch layer is recommended.

FIGURE 3.11 - 7
Grading Plan for Bioretention Basin



Designers considering species other than ones listed in **Tables 3.11-7A - 3.11-7C** should consult the following reference material on plant habitat requirements, and consider site conditions to ensure that alternative plant material will survive.

American Association of Nurserymen, Latest Edition. American Standard for Nursery Stock ASNI Z60, Washington, D.C.

Dirr, Michael A., 1975. Manual of Woody Landscape Plants, Stripes Publishing Company, Champagne, Illinois.

Hightshoe, G.L., 1988. Native Trees, Shrubs, and Vines for Urban and Rural America. Van Nostrand Reinhold, New York, New York.

Reed, P.B.Jr., 1988. National List of Species That Occur in Wetlands: Northeast. United States Fish and Wildlife Service, St. Petersburg Florida.

Reasons for exclusion of certain plants from bioretention areas include inability to meet the criteria outlined in **Tables 3.11-7A - 3.11-7C** (pollutant and metals tolerance, soil moisture and structure, ponding fluctuations, morphology, etc.). In addition, species that are considered invasive or not recommended by the Urban Design Section of the Maryland-National Capital Park and Planning Commission are not recommended (Prince George's County, 1989).

3. Site and Ecological Considerations

Each site is unique and may contain factors that should be considered before selecting plant species. An example **Plant Material Checklist** is provided in **Appendix 3E**. The checklist has been developed to assist the designer in identifying critical factors about a site that may affect both the plant material layout and the species selection.

Selection of plant species should also be based on site conditions and ecological factors. Site considerations include microclimate (light, temperature, wind), the importance of aesthetics, overall site development design and the extent of maintenance requirements, and proposed or existing buildings . Of particular concern is the increase in reflection of solar radiation from buildings upon bioretention areas. Aesthetics are critical in projects of high visibility. Species that require regular maintenance (shed fruit or are prone to storm damage) should be restricted to areas of limited visibility and pedestrian and vehicular traffic.

Interactions with adjacent plant communities are also critical. Nearby existing vegetated areas dominated by non-native invasive species pose a threat to adjacent bioretention areas. Proposed bioretention area species should be evaluated for compatibility with adjacent plant communities. Invasive species typically develop into monocultures by out competing other species . Mechanisms to avoid encroachment of undesirable species include increased maintenance, providing a soil breach between the invasive community for those species that spread through rhizomes, and providing annual removal of seedlings from wind borne seed dispersal. Existing disease or insect infestations associated with existing site conditions or in the general area that may effect the bioretention plantings.

4. Number of Species

A minimum of three species of trees and three species of shrubs should be selected to insure diversity. In addition to reducing the potential for monoculture mortality concerns, a diversity of trees and shrubs with differing rates of transpiration may ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season.

Herbaceous ground covers are important to prevent erosion of the mulch and the soil layers. Suitable herbaceous ground covers are identified in **Table 3.11-7C**.

5. Number and Size of Plants

The requisite number of plantings varies, and should be determined on an individual site basis. On average, 1000 trees and shrubs should be planted per acre. For example, a bioretention area measuring 15' x 40' would contain a combination of trees and shrubs totaling 14 individuals. The Prince Georges County recommended minimum and maximum number of individual plants and spacing are given in **Table 3.11-4.** Virginia jurisdictions with significant experience with bioretention prefer the simpler specification of 10 trees and shrubs per 1,000 square feet of basin area, with placement specified by a landscape professional to simulate natural conditions. Two to three shrubs should be specified for each tree (2:1 to 3:1 ratio of shrubs to trees).

At installation, trees should be 1.0 inches minimum in caliper, and shrubs 3 to 4 feet in height or 18 to 24 inches in spread per ASNI Z60. Ground cover may be as seed or, preferably, plugs. The relatively mature size requirements for trees and shrubs are important to ensure that the installation of plants are readily contributing to the bioretention process (i.e., evapotranspiration, pollutant uptake).

TABLE 3.11-5
Recommended Tree and Shrub Spacing

	Tree Spacing (feet)	Shrub Spacing (feet)	Total Density (stems/acre)
Maximum	19	12	400
Average	12	8	1000
Minimum	11	7	1250

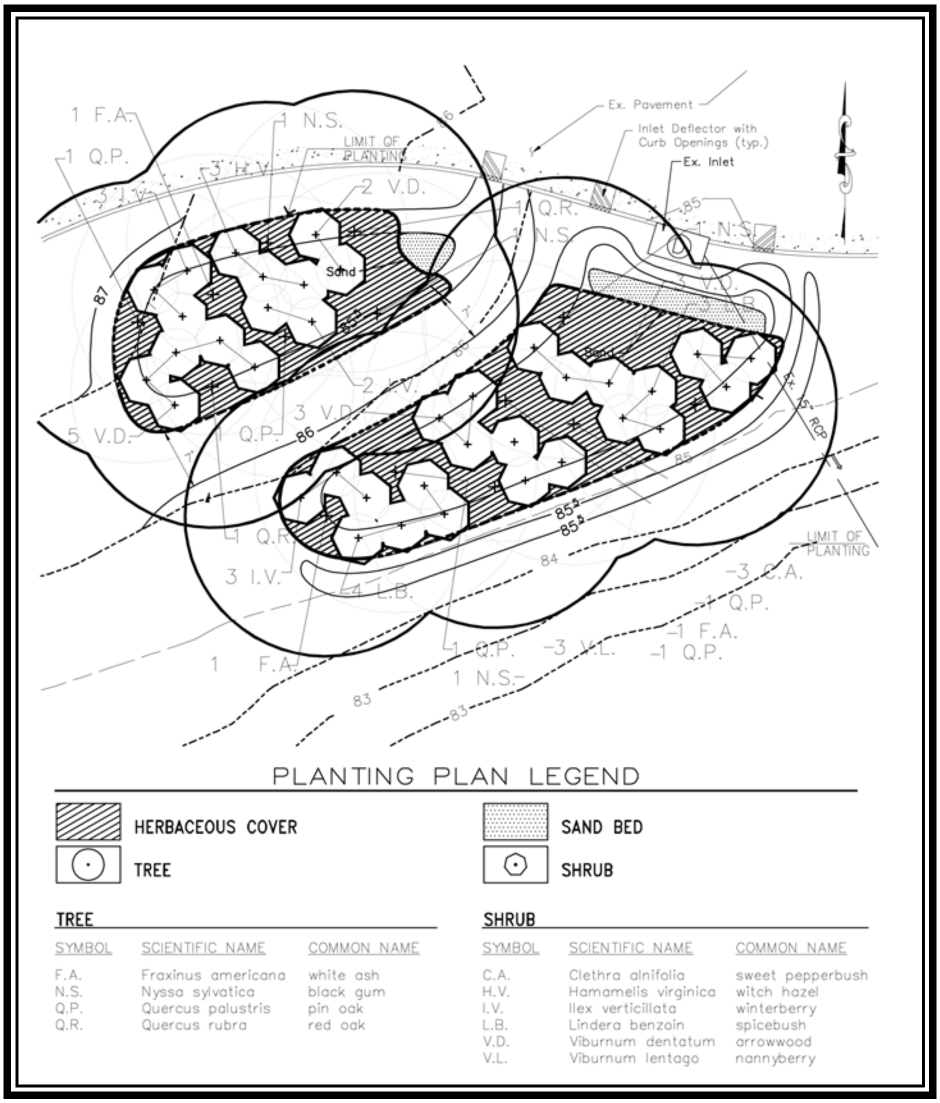
6. Plant Layout

The layout of plant material can be a flexible process; however, the designer should follow some basic guidelines. As discussed above, the designer should first review the Plant Checklist (Appendix D). The checklist table can help expose any constraints that may limit the use of a particular species and/or where a species can be installed.

There are two guidelines that should apply to all bioretention areas. First, woody plant material should not be placed within the immediate areas of where flow will be entering the bioretention area.

Besides possibly concentrating flows, trees and shrubs can be damaged as a result of the flow. Secondly, it is recommended that trees be planted primarily on the perimeter of bioretention areas, to maximize the shading and sheltering of bioretention areas to create a microclimate which will limit the extreme exposure from summer solar radiation and winter freezes and winds. An example planting plan is shown in **Figure 3.11-8**.

FIGURE 3.11 - 8
Sample Planting Plan



Planting Soil Guidelines

The characteristics of the soil play an important role in the improvement of water quality through the use of bioretention systems. The soil is a three-phase system composed of gas, liquid, and solid, each of which in the proper balance is essential to the pollutant removal achieved through bioretention. The soil anchors the plants and provides nutrients and moisture for plant growth. Microorganisms inhabit and proliferate within the soil solution, and the unsaturated pore space provides plant roots with the oxygen necessary for metabolism and growth.

A desirable planting soil would 1) be permeable to allow infiltration of runoff and 2) provide adsorption of organic nitrogen and phosphorus.

The recommended planting soil for bioretention would have the following properties:

1. Soil Texture and Structure

It is recommended that the planting soils for bioretention have a sandy loam, loamy sand, or loam texture. Experience in both Maryland and Virginia has indicated that the original soil specification contained in the Prince Georges County manual must be modified to decrease the clay content to **no more than five percent** to preclude premature failure of the basins due to clogging. Prince Georges County issued a design update in June 1998 in which the total depth of the facility is reduced to 2.5 feet by the elimination of the sand bed and the use of a soil media consisting of 50 percent sand, 20 percent leaf compost, and 30 percent topsoil. Virginia engineers with bioretention experience recommend using either the new Maryland media specification or a media of 50 percent sand and 50 percent hemic or fibric peat, using the Virginia topsoil thickness criteria in both cases, while retaining the sand bed. This could result in an overall thickness somewhat comparable to that specified in Maryland.

2. Soil Acidity

In a bioretention scheme, the desired soil pH would lie between 5.5 and 6.5 (Tisdale and Nelson, 1975). The soil acidity affects the ability of the soil to adsorb and desorb nutrients, and also affects the microbiological activity in the soil.

3. Soil Testing

The planting soil for bioretention areas must be tested prior to installation for pH, organic matter, and other chemical constituents. The soil should meet the following criteria (Landscape Contractors Association, 4th Addition, 1993):

pH range:	5.0 - 7.0
Organic matter:	Greater than 1.5
Magnesium (Mg):	100+ Units
Phosphorus (P_2O_5):	150+ Units
Potassium (K_2O):	120+ Units
Soluble salts:	not to exceed 900 ppm/.9 MMHOS/cm (soil)
	not to exceed 3,000 ppm/2.5 MMHOS/cm (organic mix)

It is recommended that one test for magnesium, phosphorus, potassium, and soluble salts be performed per borrow source or for every 500 cubic yards of soil material. It is recommended that a sieve analysis, pH, and organic matter test be performed per bioretention area.

4. Soil Placement

Placement of the planting soil in the bioretention area should be in lifts of 18 inches or less and lightly compacted. Minimal compaction effort can be applied to the soil by tamping.

Specifications for the planting soil are outlined below under **Construction Specifications**.

<u>Mulch Layer Guidelines</u>

Recent results of bioretention monitoring in Maryland has confirmed that the mulch layer plays a crucial role in the pollutant removal capabilities of the facility. This layer serves to prevent erosion and to protect the soil from excessive drying. Soil biota existing within the organic and soil layer are important in the filtering of nutrients and pollutants and assisting in maintaining soil fertility. Bioretention areas can be designed either with or without a mulch layer. If a herbaceous layer or ground cover (70 to 80% coverage) is provided, a mulch layer is not necessary. Areas should be mulched once trees and shrubs have been planted. Any ground cover specified as plugs may be installed once mulch has been applied.

The mulch layer recommended for bioretention may consist of either a standard landscape fine shredded hardwood mulch or shredded hardwood chips. Both types of mulch are commercially available and provide excellent protection from erosion.

Mulch shall be free of weed seeds, soil, roots, or any other substance not consisting of either bole or branch wood and bark. The mulch shall be uniformly applied approximately 2 to 3 inches in depth. Mulch applied any deeper than three inches reduces proper oxygen and carbon dioxide cycling between the soil and the atmosphere.

Grass clippings are unsuitable for mulch, primarily due to the excessive quantities of nitrogen built up in the material. Adding large sources of nitrogen would limit the capability of bioretention areas to filter the nitrogen associated with runoff.

<u>Plant Material Guidelines</u>

1. Plant Material Source

The plant material should conform to the current issue of the <u>American Standard for Nursery Stock</u> published by the American Association of Nurserymen. Plant material should be selected from certified nurseries that have been inspected by state or federal agencies. The botanical (scientific) name of the plant species should be in accordance with a standard nomenclature source such as Birr, 1975.

Some of the plant species listed in **Tables 3.11-7A - 3.11-7C**, Recommended Plant Species For Use in Bioretention may be unavailable from standard nursery sources. These are typically species native to Virginia and may not be commonly used in standard practices. Designers may need to contact nurseries specializing in native plants propagation.

2. Installation

The success of bioretention areas is dependent on the proper installation specifications that are developed by the designer and subsequently followed by the contractor. The specifications include the procedures for installing the plants and the necessary steps taken before and after installation. Specifications designed for bioretention should include the following considerations:

- Sequence of Construction
- Contractors Responsibilities
- Planting Schedule and Specifications
- Maintenance
- Warranty

The sequence of construction describes site preparation activities such as grading, soil amendments, and any pre-planting structure installation. It also should address erosion and sediment control procedures. Erosion and sediment control practices should be in place until the entire bioretention area is completed. The contractors responsibilities should include all the specifications that directly effect the contractor in the performance of his or her work. The responsibilities include any penalties for unnecessarily delayed work, requests for changes to the design or contract, and exclusions from the contract specifications such as vandalism to the site, etc.

The planting schedule and specifications include type of material to be installed (e.g., ball and burlap, bare root, or containerized material), timing of installation, and post installation procedures. Balled and burlapped and containerized trees and shrubs should be planted during the following periods: March 15 through June 30 and September 15 through November 15. Ground cover excluding grasses and legumes can follow tree and shrub planting dates. Grasses and legumes typically should be planted in the spring of the year. The planting of trees and shrubs should be performed by following the planting specifications set forth in **MS 3.05, Landscaping. MS 3.05** specifications provide guidelines that insure the proper placement and installation of plant material. Designers may choose to use other specifications or to modify the jurisdiction specifications. However, any deviations from the jurisdiction specifications need to address the following:

- transport of plant material
- preparation of the planting pit
- installation of plant material
- stabilization seeding (if applicable)
- maintenance

An example of general planting specification for trees and shrubs and ground cover is given under **Construction Specifications** below.

3. Warranties

Typically, a warranty is established as a part of any plant installation project. The warranty covers all components of the installation that the contractor is responsible for. The plant and mulch installation for bioretention should be performed by a professional landscape contractor. An example of standard guidelines for landscape contract work is provided below:

- The contractor shall maintain a one (1) calendar year 80% care and replacement warranty for all planting.

- The period of care and replacement shall begin after inspection and approval of the complete installation of all plants and continue for one calendar year.

- Plant replacements shall be in accordance with the maintenance schedule.

<u>Plant Growth and Soil Fertility</u>

A discussion of plant growth and soil fertility development over time is important to for estimating the success and lifespan of bioretention areas. The physical, chemical, and biological factors influencing plant growth and development will vary over time as well as for each bioretention area. However, there are certain plant and soil processes that will be the same for all bioretention areas.

1. Plant Growth

The role of plants in bioretention includes uptake of nutrients and pollutants and evapotranspiration of stormwater runoff. The plant material, especially ground covers, are expected to contribute to the evapotranspiration process within the first year of planting. However, trees and shrubs that have been recently planted demonstrate slower rates of growth for the first season due to the initial shock of transplanting. The relative rate of growth is expected to increase to normal rates after the second growth season.

The growth rate for plants in bioretention areas will follow a similar pattern to that of other tree and shrub plantings (reforestation projects, landscaping). For the first two years, the majority of tree and shrub growth occurs with the expansion of the plant root system. By the third or fourth year the growth of the stem and branch system dominates increasing the height and width of the plant. The comparative rate of growth between the root and stem and branch system remains relatively the same throughout the lifespan of the plant. The reproductive system (flowers, fruit) of the plants is initiated last.

The growth rates and time for ground covers to become acclimated to bioretention conditions is much faster than for trees and shrubs. The rate of growth of a typical ground cover can often exceed 100 percent in the first year. Ground covers are considered essentially mature after the first year of growth. The longevity of ground covers will be influenced by the soil fertility and chemistry as well as physical factors, such as shading and overcrowding from trees and shrubs and other ecological and physical factors.

Plants are expected to increase their contribution to the bioretention concept over time, assuming that growing conditions are suitable. The rate of plant growth is directly proportional to the environment in which the plant is established. Plants grown in optimal environments experience greater rates of growth. One of the primary factors determining this is soil fertility.

2. Soil Fertility

Initially, soil in bioretention areas will lack a mature soil profile. It is expected that over time discrete soil zones referred to as horizons will develop. The development of a soil profile and the individual horizons is determined by the influence of the surrounding environment including physical, chemical, and biological processes. Two primary processes important to horizon development is microbial action and the percolation of runoff in the soil.

Horizons expected to develop in bioretention areas include an organic layer, followed by two horizons where active leaching (eluviation) and accumulation (illuvation) of minerals and other substances occur. The time frame for the development of soil horizons will vary greatly. As an average, soil horizons may develop within three to ten years. The exception to this is the formation of the organic layer often within the first or second year (Brady, 1984).

The evaluation of soil fertility in bioretention may be more dependent on the soil interactions relative to plant growth than horizon development. The soil specified for bioretention is important in filtering pollutants and nutrients as well as supply plants with water, nutrients, and support. Unlike plants that will become increasingly beneficial over time, the soil will begin to filter the storm water runoff immediately. It is expected that the ability to filter pollutants and nutrients may decrease over time, reducing the soil fertility accordingly. Substances from runoff such as salt and heavy metals eventually disrupt normal soil functions by lowering the cation exchange capacity (CEC). The CEC, the ability to allow for binding of particles by ion attraction, decreases to the point that the transfer of nutrients for plant uptake can not occur. However, the environmental factors influencing each bioretention area will vary enough that it is difficult to predict for the lifespan of soils. Findings from other stormwater management systems suggest an accumulation of substances eliminating soil fertility within five years. The monitoring of soil development in bioretention areas will help develop better predictions on soil fertility and development.

Construction Specifications

The construction of bioretention basins should be in accordance with the following Minimum Specifications and Standards where applicable: **3.1: Earthen Embankments; 3.2: Principal Spillways; 3.3: Vegetated Emergency Spillways; 3.4: Sediment Forebays; 3.5: Landscaping; 3.10: General Infiltration Practices**, as well as the additional criteria set forth below. These specifications have been adapted from the Prince George's County, Maryland publication, ***Design Manual for Use of Bioretention in Stormwater Management***.

Sequence of Construction

The sequence of various phases of basin construction must be coordinated with the overall project construction. As with other infiltration practices, rough excavation of the basin may be scheduled with the rough grading of the project to permit use of the excavated material as fill elsewhere on the site. However, the bioretention basin must not be constructed or placed in service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may otherwise load the newly formed basin with a large load of fine sediment, seriously impairing the natural infiltration ability of the basin floor. For these reasons, **the locations of infiltration bioretention basins must NOT be used for sediment basins for erosion and sediment protection during site construction.** The sequence of construction shall be as follows:

1. Install Phase I erosion and sediment control measures for the site.

2. Grade each site to elevations shown on plan. Initially, the basin floor may be excavated to within one foot of its final elevation. Excavation to finished grade shall be deferred until all disturbed areas within the watershed have been stabilized and protected. Construct curb openings, and/or remove and replace existing concrete as specified on the plan. Curb openings shall be blocked or other measures taken to prohibit drainage from entering construction area.

3. Complete construction on the watershed and stabilize all areas draining to the Bioretention basin.

4. Remove Phase I sediment control devices at direction of designated inspector.

5. Install Phase II erosion and sediment control measures for bioretention area.

6. Remove all accumulated sediment and excavate Bioretention Area to proposed depth. Use relatively light, tracked equipment to avoid compaction of the basin floor. After final grading is completed, deeply till the basin floor with rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

7. Install the infiltration chambers, piping, manifolds, drains, vents, and infiltration stone in accordance in with the specifications and directions of the chamber manufacturer. Install a six-inch layer of washed, 1/4-inch pea gravel above the stone. Install a 1-foot layer of ASTM C-33 concrete sand on top of the pea gravel. Lightly compact with a landscaping roller.

8. After confirmation that soil meets specs by performing the requisite gradation and chemical tests (see below), fill Bioretention Area with planting soil and sand, as shown in the plans and detailed in the specifications.

9. Install vegetation and ground cover specified in the planting plan for Bioretention Area.

Install mulch layer if called for in the design.

10. Place sod, EC fabric, or non erosive lining (depending on inflow velocities) in the inlet channel and/or filter strips.

11. Upon authorization from designated inspector, remove all sediment controls and stabilize all disturbed areas. Unblock curb openings, and provide drainage to the Bioretention Areas.

Bioretention Area Soil Specifications

1. Planting Soil

The bioretention areas shall contain a planting soil mixture of 50% sand, 30% leaf compost (fully composted, NOT partially rotted leaves), and 20% topsoil. Topsoil shall be sandy loam or loamy sand of uniform composition, containing no more than 5% clay, free of stones, stumps, roots, or similar objects greater than one inch, brush, or any other material or substance which may be harmful to plant growth, or a hindrance to plant growth or maintenance.

The top soil shall be free of plants or plant parts of Bermuda grass, Quack grass, Johnson grass, Mugwort, Nutsedge, Poison Ivy, Canadian Thistle or others as specified. It shall not contain toxic substances harmful to plant growth.

The top soil shall be tested and meet the following criteria:

pH range:	5.0 - 7.0
Organic matter:	Greater than 1.5
Magnesium (Mg):	100+ Units
Phosphorus (P_2O_5):	150+ Units
Potassium (K_2O):	120+ Units
Soluble salts:	not to exceed 900 ppm/.9 MMHOS/cm (soil)
	not to exceed 3,000 ppm/2.5 MMHOS/cm (organic mix)

The following testing frequencies shall apply to the above soil constituents:

pH, Organic Matter: 1 test per 90 cubic yards, but no more than 1 test per Bioretention Area

Magnesium, Phosphorus, Potassium, Soluble Salts:

1 test per 500 cubic yards, but no less than 1 test per borrow source

One grain size analysis shall per performed per 90 cubic yards of planting soil, but no less than 1 test per Bioretention Area. Soil tests must be verified by a qualified professional.

2. Mulch

A mulch layer shall be provided on top of the planting soil. An acceptable mulch layer shall include shredded hardwood or shredded wood chips or other similar product.

Of the approved mulch products all must be well aged, uniform in color, and free of foreign material including plant material.

3. Sand

The sand for bioretention basins when utilized, shall be ASTM C-33 Concrete Sand and free of deleterious material.

4. Compaction

Soil shall be placed in lifts less than 18 inches and lightly compacted (minimal compactive effort) by tamping or rolled with a hand-operated landscape roller.

<u>Bioretention Area Planting Specifications</u>

1. Root stock of the plant material shall be kept moist during transport from the source to the job site and until planted.

2. Walls of planting pit shall be dug so that they are vertical.

3. The diameter of the planting pit must be a minimum of six inches (6") larger than the diameter of the ball of the tree.

4. The planting pit shall be deep enough to allow 1/8 of the overall dimension of the root ball to be above grade. Loose soil at the bottom of the pit shall be tamped by hand.

5. The appropriate amount of fertilizer is to be placed at the bottom of the pit (see below for fertilization rates).

6. The plant shall be removed from the container and placed in the planting pit by lifting and carrying the plant by its' ball (never lift by branches or trunk).

7. Set the plant straight and in the center of the pit so that approximately 1/8 of the diameter of the root ball is above the final grade.

8. Backfill planting pit with existing soil.

9. Make sure plant remains straight during backfilling procedure.

10. Never cover the top of the ball with soil. Mound soil around the exposed ball.

11. Trees shall be braced by using 2" by 2" white oak stakes. Stakes shall be placed parallel to walkways and buildings. Stakes are to be equally spaced on the outside of the tree ball. Utilizing hose and wire the tree is braced to the stakes.

12. Because of the high levels of nutrients in stormwater runoff to be treated, bioretention basin plants should not require chemical fertilization.

Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific Facilities may require additional measures not discussed here.

A schedule of recommended maintenance for bioretention areas is given in **Table 3.11-5**. The table gives general guidance regarding methods, frequency, and time of year for maintenance.

Planting Soil

Urban plant communities tend to become very acidic due to precipitation as well as the influences of storm water runoff. For this reason, it is recommended that the application of alkaline, such as limestone, be considered once to twice a year. Testing of the pH of the organic layer and soil, should precede the limestone application to determine the amount of limestone required.

Soil testing should be conducted annually so that the accumulation of toxins and heavy metals can be detected or prevented. Over a period of time, heavy metals and other toxic substances will tend to accumulate in the soil and the plants. Data from other environs such as forest buffers and grass swales suggest accumulation of toxins and heavy metals within five years of installation. However, there is no methodology to estimate the level of toxic materials in the bioretention areas since runoff, soil, and plant characteristics will vary from site to site.

As the toxic substances accumulate, the plant biologic functions may become impaired, and the plant may experience dwarfed growth followed by mortality. The biota within the soil can also become void and the natural soil chemistry may be altered. The preventative measures would include the removal of the contaminated soil. In some cases, removal and disposal of the entire soil base as well as the plant material may be required.

Mulch

Bioretention areas should be mulched once the planting of trees and shrubs has occurred. Any ground cover specified as plugs may be installed once the area has been mulched. Ground cover established by seeding and\or consisting of grass should not be covered with mulch.

Plant Materials

An important aspect of landscape architecture is to design areas that require little maintenance. Certain plant species involve maintenance problems due to dropping of fruit or other portions of the plant. Another problem includes plants, primarily trees, that are susceptible to windthrow, which creates a potential hazard to people and property (parked cars). As a result, some plant species will be limited to use in low-traffic areas.

Ongoing monitoring and maintenance is vital to the overall success of bioretention areas. Annual maintenance will be required for plant material, mulch layer, and soil layer. A maintenance schedule should include all of the main considerations discussed below. The maintenance schedule usually includes maintenance as part of the construction phase of the project and for life of the design. A example maintenance schedule is shown in **Table 3.11-6**.

Maintenance requirements will vary depending on the importance of aesthetics. Soil and mulch layer maintenance will be most likely limited to correcting areas of erosion. Replacement of mulch layers may be necessary every two to three years. Mulch should be replaced in the spring. When the mulch layer is replaced, the previous layer should be removed first. Plant material upkeep will include addressing problems associated with disease or insect infestations, replacing dead plant material, and any necessary pruning.

Control of Sediments on the Drainage Shed

Care must be taken to protect the bioretention basin from excessive sediments from the drainage shed. Whenever additional land disturbing activity takes place in the area draining to the basin, effective erosion and sediment control measures must first be put in place to exclude sediments from the basin. Performance based special measures over and above those specified in the ***Virginia Erosion and Sediment Control Handbook***, latest edition, may be required to assure that the bioretention basin is not damaged by such land disturbance. When sand or other street abrasives are used during the snow or icing conditions to provide traction on roadways or parking lots draining to bioretention basins, the pavement should be power/vacuum swept as soon as freezing weather abates to prevent damage to the basins.

Checklists

The Construction Inspection and As-Built Checklist provided in **Appendix 3E** is for use in inspecting bioretention basins during construction, and where required by local jurisdiction, engineering certification of the basin construction. The Operation and Maintenance Inspection Checklist, also found in **Appendix 3E**, is for use in conducting maintenance inspections of bioretention basins.

TABLE 3.11 - 6
Example Maintenance Schedule for Bioretention Basin

Description	Method	Frequency	Time of the year
SOIL			
Inspect and Repair Erosion	Visual	Monthly	Monthly
ORGANIC LAYER			
Remulch any void areas	By hand	Whenever needed	Whenever needed
Remove previous mulch layer before applying new layer (optional)	By hand	Once every two to three years	Spring
Any additional mulch added (optional)	By hand	Once a year	Spring
PLANTS			
Removal and replacement of all dead and diseased vegetation considered beyond treatment	See planting specifications	Twice a year	3/15 to 4/30 and 10/1 to 11/30
Treat all diseased trees and shrubs	Mechanical or by hand	N/A	Varies, depends on insect or disease infestation
Watering of plant material shall take place at the end of each day for fourteen consecutive days after planting has been completed	By hand	Immediately after completion of project	N/A
Replace stakes after one year	By hand	Once a year	Only remove stakes In the spring
Replace any deficient stakes or wires	By hand	N/A	Whenever needed
Check for accumulated sediments	Visual	Monthly	Monthly

TABLE 3.11-7A RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- TREE SPECIES

Species	Moisture Regime		Tolerance						Morphology			General Characteristics			Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects Disease	Exposure	Form	Height	Root System	Native	Non-native	Wildlife	
Acer rubrum red maple	FAC	Mesic - Hydric	4-6	H	H	H	H	Partial Sun	Single to multi-stem tree	50-70'	Shallow	Yes	-	High	-
Amelanchier canadensis shadbush	FAC	Mesic	2-4	H	M	-	H	Partial Sun	Single to multi-stem tree	35-50'	Shallow	Yes	-	High	Not recommended for full sun.
Betula nigra river birch	FACW	Mesic - Hydric	4-6	-	M	M	H	Partial Sun	Single to multi-stem tree	50-75'	Shallow	Yes	-	High	Not susceptible to bronze birch borer.
Betula populifolia gray birch	FAC	Xeric - Hydric	4-6	H	H	M	H	Partial Sun	Single to multi-stem tree	35-50'	Shallow to deep	-	Yes	High	Native to New England area.
Fraxinus americana white ash	FAC	Mesic	2-4	M	H	H	H	Sun	Large tree	50-80'	Deep	Yes	-	Low	-
Fraxinus pennsylvanica green ash	FACW	Mesic	4-6	M	H	H	H	Partial Sun	Large tree	40-65'	Shallow to deep	Yes	-	Low	-
Ginkgo biloba Maidenhair tree	FAC	Mesic	2-4	H	H	H	H	Sun	Large tree	50-80'	Shallow to deep	-	Yes	Low	Avoid female species-offensive odor from fruit.
Gleditsia triacanthos honeylocust	FAC	Mesic	2-4	H	M	-	M	Sun	Small canopied large tree	50-75'	Shallow to deep variable taproot	Yes	-	Low	Select thornless variety.
Juniperus virginiana eastern red cedar	FACU	Mesic - Xeric	2-4	H	H	-	H	Sun	Dense single stem tree	50-75'	Taproot	Yes	-	Very High	Evergreen
Koelreuteria paniculata golden-rain tree	FACU	Mesic	2-4	H	H	H	H	Sun	Round, dense shade tree	20-30'	Shallow	-	Yes	No	-
Liquidambar styraciflua sweet gum	FAC	Mesic	4-6	H	H	H	M	Sun	Large tree	50-70'	Deep taproot	Yes	-	High	Edge and perimeter; fruit is a maintenance problem.
Nyssa sylvatica black gum	FACW	Mesic - Hydric	4-6	H	H	H	H	Sun	Large tree	40-70'	Shallow to deep taproot	Yes	-	High	-

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

NOTE: Heights shown in table are under ideal conditions in rural settings. They do not reflect urban conditions, under which plants do not commonly survive to such maturity.

TABLE 3.11-7A RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- TREE SPECIES

Species	Moisture Regime		Tolerance						Morphology			General Characteristics			Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects Disease	Exposure	Form	Height	Root System	Native	Non-native	Wildlife	
Platanus acerifolia London plane-tree	FACW	Mesic	2-4	H	-	-	M	Sun	Large tree	70-80'	Shallow	-	Yes	Low	Tree roots can heave sidewalks.
Platanus occidentalis sycamore	FACW	Mesic - Hydric	4-6	M	M	M	M	Sun	Large tree	70-80'	Shallow	Yes	-	Med.	Edge and perimeter; fruit is a maintenance problem; tree is also prone to windthrow.
Populus deltoides eastern cottonwood	FAC	Xeric - Mesic	4-6	H	H	H	L	Sun	Large tree with spreading branches	75-100'	Shallow	Yes	-	High	Short lived.
Quercus bicolor swamp white oak	FACW	Mesic to wet Mesic	4-6	H	-	H	H	Sun to partial sun	Large tree	75-100'	Shallow	Yes	-	High	One of the faster growing oaks.
Quercus coccinea scarlet oak	FAC	Mesic	1-2	H	M	M	M	Sun	Large tree	50-75'	Shallow to deep	Yes	-	High	-
Quercus macrocarpa bur oak	FAC	Mesic to wet Mesic	2-4	H	H	H	M	Sun	Large spreading tree	75-100'	Taproot	-	Yes	High	Native to midwest.
Quercus palustris pin oak	FACW	Mesic - Hydric	4-6	H	H	H	M	Sun	Large tree	60-80'	Shallow to deep taproot	Yes	-	High	-
Quercus phellos willow oak	FACW	Mesic to wet Mesic	4-6	H	-	-	H	Sun	Large tree	55-75'	Shallow	Yes	-	High	Fast growing oak.
Quercus rubra red oak	FAC	Mesic	2-4	M	H	M	M	Sun to partial sun	Large spreading tree	60-80'	Deep taproot	Yes	-	High	-

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

NOTE: Heights shown in table are under ideal conditions in rural settings. They do not reflect urban conditions, under which plants do not commonly survive to such maturity.

TABLE 3.11-7A RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- TREE SPECIES

Species	Moisture Regime		Tolerance						Morphology			General Characteristics			Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects Disease	Exposure	Form	Height	Root System	Native	Non-native	Wildlife	
Robinia pseudo-acacia black locust	FAC	Mesic - Xeric	2-4	H	H	H	M	Sun	Typically tall and slender	30-50'	Shallow	Yes	-	Low	Edge and perimeter; fruit is a maintenance problem; tree is also prone to windthrow.
Sophora japonica Japanese pagoda tree	FAC	Mesic	1-2	M	M	-	M	Sun	Shade tree	40-70'	Shallow	-	Yes	Low	Fruit stains sidewalks etc.
Taxodium distichum bald cypress	FACW	Mesic - Hydric	4-6	-	-	M	H	Sun to partial sun	Typically single stem tree	75-100'	Shallow	Yes	-	Low	Not well documented for planting in urban areas.
Zelkova serrata Japanese zelkova	FACU	Mesic	1-2	M	M	-	H	Sun	Dense shade tree	60-70'	Shallow	-	Yes	Low	Branches can split easily in storms.

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

NOTE: Heights shown in table are under ideal conditions in rural settings. They do not reflect urban conditions, under which plants do not commonly survive to such maturity.

TABLE 3.11-7B RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- SHRUB SPECIES

Species	Moisture Regime		Tolerance						Morphology			General Characteristics			Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects Disease	Exposure	Form	Height	Root System	Native	Non-native	Wildlife	
Berberis koreana barberry	FAC	Mesic	2-4	H	H	H	M	Sun to partial sun	Oval shrub	4-6'	Shallow	-	Yes	Low	-
Berberis thunbergii Japanese barberry	FAC	Mesic	2-4	H	H	H	M	Sun	Rounded, broad dense shrub	5-7'	Shallow	-	Yes	Med.	-
Clethra alnifolia sweet pepperbush	FAC	Mesic to wet Mesic	2-4	H	-	-	H	Sun to partial sun	Ovoid shrub	6-12'	Shallow	Yes	-	Med.	Coastal plain species
Cornus Stolonifera red osier dogwood	FACW	Mesic - Hydric	2-4	H	H	H	M	Sun or shade	Arching, spreading shrub	8-10'	Shallow	Yes	-	High	Needs more consistant moisture levels.
Euonymus alatus winged euonymous	FAC	Mesic	1-2	H	H	H	M	Sun or shade	Flat, dense horizontal branching shrub	5-7'	Shallow	-	Yes	No	-
Euonymus europaeus spindle-tree	FAC	Mesic	1-2	M	M	M	M	Sun to partial sun	Upright dense oval shrub	10-12'	Shallow	-	Yes	No	-
Hamamelis virginiana witch-hazel	FAC	Mesic	2-4	M	M	M	M	Sun or shade	Vase-like compact shrub	4-6'	Shallow	Yes	-	Low	-
Hypericum densiflorum common St. John's wort	FAC	Mesic	2-4	H	M	M	H	Sun	Ovoid shrub	3-6'	Shallow	Yes	-	Med.	-
Ilex glabra inkberry	FACW	Mesic to wet Mesic	2-4	H	H	-	H	Sun to partial sun	Upright dense shrub	6-12'	Shallow	Yes	-	High	Coastal plain species
Ilex verticillata winterberry	FACW	Mesic to wet Mesic	2-4	L	M	-	H	Sun to partial sun	Spreading shrub	6-12'	Shallow	Yes	-	High	-
Juniperus communis "compressa" common juniper	FAC	Dry Mesic - Mesic	1-2	M	H	H	M - H	Sun	Mounded shrub	3-6'	Deep taproot	-	Yes	High	Evergreen

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

TABLE 3.11-7B RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- SHRUB SPECIES

Species	Moisture Regime		Tolerance						Morphology			General Characteristics			Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects Disease	Exposure	Form	Height	Root System	Native	Non-native	Wildlife	
Juniperus horizontalis "Bar Harbor" creeping juniper	FAC	Dry Mesic - Mesic	1-2	M	H	H	M - H	Sun	Matted shrub	0-3'	Deep taproot	-	Yes	High	Evergreen
Lindera benzoin spicebush	FACW	Mesic to wet Mesic	2-4	H	-	-	H	Sun	Upright shrub	6-12'	Deep	Yes	-	High	-
Myrica pennsylvanica bayberry	FAC	Mesic	2-4	H	M	M	H	Sun to partial sun	Rounded, compacted shrub	6-8'	Shallow	Yes	-	High	Coastal plain species
Physocarpus opulifolius ninebark	FAC	Dry Mesic to wet Mesic	2-4	M	-	-	H	Sun	Upright shrub	6-12'	Shallow	Yes	-	Med.	May be difficult to locate.
Viburnum cassinoides northern wild raisin	FACW	Mesic	2-4	H	H	H	H	Sun to partial sun	Rounded, compacted shrub	6-8'	Shallow	Yes	-	High	-
Viburnum dentatum arrow-wood	FAC	Mesic	2-4	H	H	H	H	Sun to partial sun	Upright, multi-stemmed shrub	8-10'	Shallow	Yes	-	High	-
Viburnum lentago nannyberry	FAC	Mesic	2-4	H	H	H	H	Sun to partial sun	Upright, multi-stemmed shrub	8-10'	Shallow	Yes	-	High	-

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

TABLE 3.11-7C RECOMMENDED PLANT SPECIES FOR USE IN BIORETENTION --- HERBACEOUS SPECIES

Species	Moisture Regime		Tolerance						Morphology			General Characteristics			Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects Disease	Exposure	Form	Height	Root System	Native	Non-native	Wildlife	
Agrostis alba redtop	FAC	Mesic - Xeric	1-2	H	-	H	H	Shade	Grass	2-3'	Fiberous Shallow	Yes	-	High	-
Andropogon gerardi bluejoint	FAC	Dry Mesic - Mesic	1-2	-	-	-	-	Sun	Grass	2-3'	Fiberous Shallow	Yes	-	High	-
Deschampsia caespitosa tufted hairgrass	FACW	Mesic to wet Mesic	2-4	H	-	H	H	Sun	Grass	2-3'	Fiberous Shallow	Yes	-	High	May become invasive.
Hedera helix English ivy	FACU	Mesic	1-2	-	-	-	H	Sun	Evergreen ground cover	-	Fiberous Shallow	-	Yes	Low	-
Lotus Corniculatus birdsfoot-trefoil	FAC	Mesic - Xeric	1-2	H	L	H	H	Sun	Grass	2-3'	Fiberous Shallow	Yes	-	High	Member of the legume family.
Pachysandra terminalis Japanese pachysandra	FACU	Mesic	1-2	-	-	-	M	Shade	Evergreen ground cover	-	Fiberous Shallow	-	Yes	Low	-
Panicum virgatum switch grass	FAC to FACU	Mesic	2-4	H	-	-	H	Sun or Shade	Grass	4-5'	Fiberous Shallow	Yes	-	High	Can spread fast and reach height of 6'.
Parthenocissus Tricuspida Boston ivy	FACU	Mesic	1-2	-	-	-	H	Shade	Evergreen ground cover		Fiberous Shallow	-	Yes	Low	May need to be trimmed back often.
Vinca major large periwinkle	FACU	Mesic	1-2	-	-	-	H	Shade	Evergreen ground cover	-	Fiberous Shallow	-	Yes	Low	Sensitive to soil compaction and pH changes.

H High Tolerance
M Medium Tolerance
L Low Tolerance

FAC Facultative - Equally likely to occur in wetlands or non-wetlands.
FACU Facultative Upland - Usually occur in non-wetlands, but occasionally found in wetlands.
FACW Facultative Wetland - Usually occur in wetlands, but occasionally found in non-wetlands.

MINIMUM STANDARD 3.11A

BIORETENTION FILTERS

Definition

Bioretention basins that rely on infiltration (**MINIMUM STANDARD 3.11: BIORETENTION BASINS**) may not be feasible in many ultra-urban settings because of the proximity of building foundations or because soils are not conducive to exfiltration from the basin. **Bioretention Filters** were developed for use in such circumstances.

Bioretention soil media filters are essentially bioretention basins with the infiltration chamber gallery equipped with a permanent and continuous connection to the storm sewer system. The bioretention basin shown in **Figure 3.11A-1** illustrates a bioretention basin equipped to function as a filter.

When used in areas underlain by marine clays or in proximity to building foundations, the entire basin must be provided with a dense clay or geomembrane liner. When the filter concept must be used simply because of low percolation rates of the soil, the liner may be omitted. The vertical sand column is also optional on a bioretention filter.

Purpose

Water Quality Enhancement

Like bioretention basins, bioretention filters are used primarily for water quality control. Bioretention filters enhance the quality of stormwater runoff through the processes of adsorption, filtration, volitization, ion exchange, microbial and decomposition prior to collection of the treated effluent in the collector pipe system. Microbial soil processes, evapotranspiration, and nutrient uptake in plants also come into play (Bitter and Bowers, 1995). The manner in which these processes work is discussed under **MINIMUM STANDARD 3.11, BIORETENTION BASINS**. The minimum widths and lengths for bioretention basins (10' and 15', respectively) also apply to bioretention filters. However, since runoff will be treated faster in a bioretention filter, it may be pooled to a maximum depth of 1 foot above the basin floor rather than the 0.5 feet allowed in a bioretention basin. **Table 3.11A-1** contains the target removal efficiencies for bioretention filters in which a **mature** forest community has been created, based on the volume of runoff to be filtered.

FIGURE 3.11A-1
Bioretention Filter

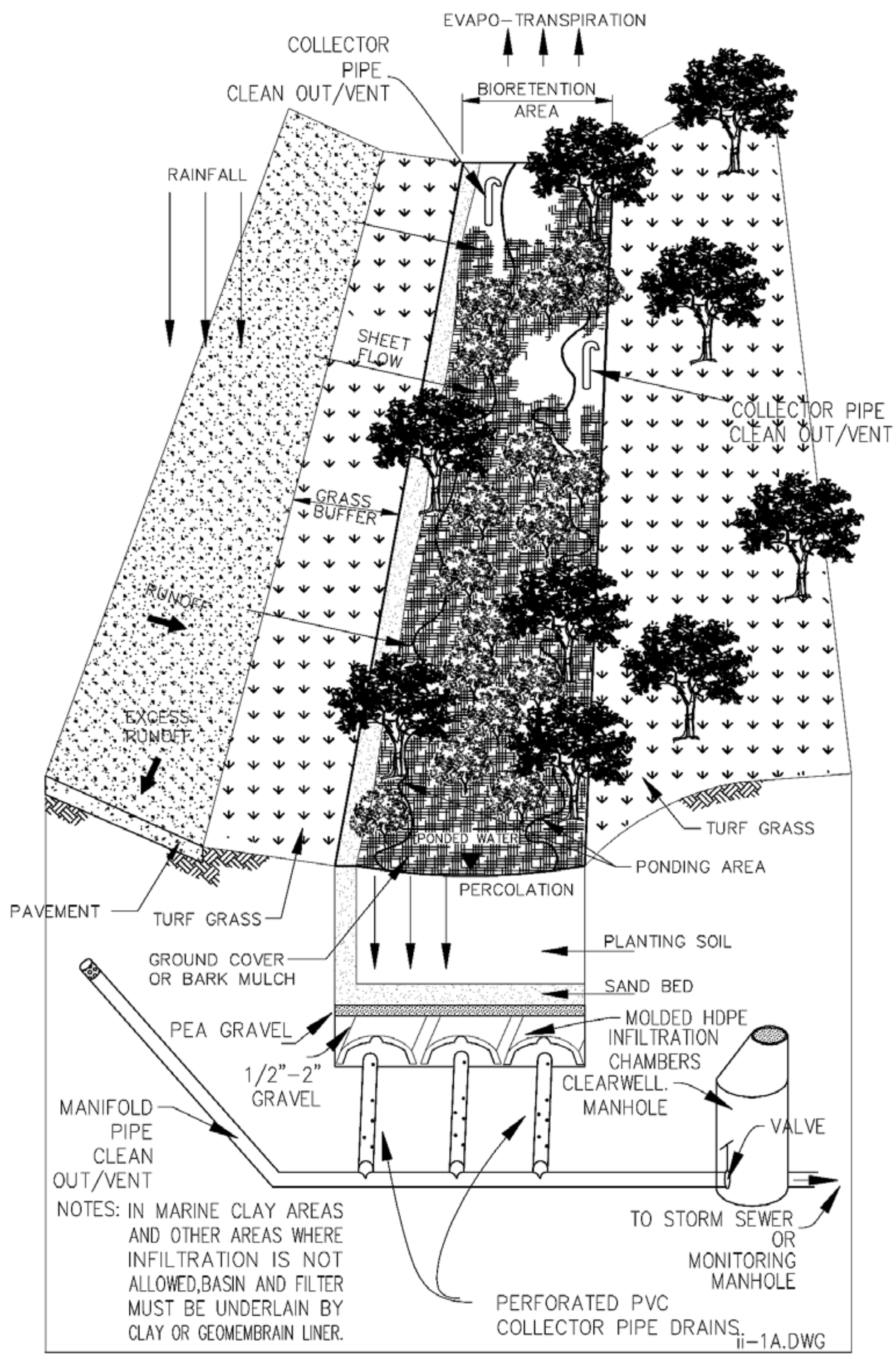


TABLE 3.11A - 1
Pollutant Removal Efficiencies for Bioretention Filters

BMP Description	Target Pollutant Removal Efficiency (Phosphorous)
Bioretention filter with capture and treatment volume equal to 0.5 inches of runoff from the impervious area.	50%
Bioretention filter with capture and treatment volume equal to 1.0 inches of runoff from the impervious area.	65%

Flood Control and Channel Erosion Control

The amount of flood and channel erosion control protection provided by bioretention basins depends on the local rainfall frequency spectrum, the amount of pre-development (or pre-redevelopment) impervious cover, the amount of post-development impervious cover, and the volume of runoff captured and infiltered by the basin(s). The effect of the BMPs on peak flow rates from the drainage shed must be examined As with other infiltration practices, bioretention basins tend to reverse the consequences of urban development by reducing peak flow rates and providing groundwater discharge.

Conditions Where Practice Applies

Bioretention Filters are generally suited for almost all types of development, from single-family residential to fairly high density commercial projects. They are attractive for higher density projects because of their relatively high removal efficiency. The critical prerequisite is the existence of a deep enough storm sewer to accept drainage from the collector pipe system by gravity flow. All of the applications shown in **Figures 3.11-2** through **3.11-6** under **MS 3.11** may be built as bioretention filters. As with bioretention basins, for large applications, several connected bioretention filters (another type of "Green Alleys") are preferable to a single, massive filter. Such systems are especially desirable along the landward boundary of reduced Chesapeake Bay Resource Protection Areas. **MS 3.11B** discusses this system. Considering the character of bioretention basins, some jurisdictions may qualify them as buffer restoration.

Planning Considerations

Site Conditions

Except for those dealing with proper soils to accept infiltration and sizing of the filters, all of the **Site Conditions** considerations for bioretention basins contained in **MINIMUM STANDARD 3.11: BIORETENTION BASINS** also apply to bioretention filters. The same drainage area range applies, as do the same **Location Considerations.** In addition to site conditions, the following apply specifically to bioretention filters.

1. Sizing Guidelines

For planning purposes, assume that the floor area of a bioretention filter will be 2.5% of the impervious area draining to the filter if 0.5 inches of runoff are to be treated and 5.0% of the impervious area on the drainage shed if the first 1.0 inches of runoff are to be treated.

2. Aesthetic Considerations

All of the discussion of aesthetics under **MINIMUM STANDARD 3.11: BIORETENTION BASINS** apply equally to bioretention filters. Overall aesthetics of the bioretention filters must be integrated into the site plan and stormwater concept plan from their inception. Biomorphic shapes which follow the ground contours should be used rather than angular shapes. The bioretention filter should be essentially almost invisible upon completion, blending in with the other landscaping of the site. Both the stormwater engineer and the landscaping planner must participate in the layout of the facilities and infrastructure to be placed on the site.

Sediment Control

All of the **Sediment Control** considerations for bioretention basins under **MS 3.11: Bioretention Basins** also apply to bioretention filters.

Like bioretention basins, bioretention filters should be constructed only AFTER the site work is complete and stabilization measures have been implemented. Experience with bioretention basins and soil media filters has demonstrated that bioretention filters must be protected from all sediment loads.

Bioretention filters must retain sediment control protection until stabilization of the upland site is functional to control the sediment load from denuded areas. Provisions to bypass the stormwater away from the bioretention filter during the stabilization period must be implemented.

General Design Criteria

The purpose of this section is to provide minimum criteria for the design of bioretention filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements. Bioretention filters which capture and treat the first one inch of runoff from impervious surfaces may also provide streambank erosion protection.

General

The design of bioretention filters should be in accordance with the following Minimum Standards where applicable: **3.1: Earthen Embankments, 3.2: Principal Spillways, 3.3: Vegetated Emergency Spillways, 3.4: Sediment Forebay,** as well as the additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for the particular design but also for ensuring long-term operation.

Integration of the bioretention filters into the general landscaping scheme of the project must be coordinated with the landscaping professional at the inception of the design process. Use of such techniques as biomorphic shapes to present a pleasing aesthetic appearance is of equal importance with hydrological and hydraulic functioning of the basins. Properly designed bioretention filters should not be readily identifiable as stormwater BMPs by the lay observer.

Basin Sizing Methodology

In Virginia, bioretention filters are designed to filter the treatment quantity into the underlying gravel bed and collector pipe system. **Bioretention filters are sized using the same sizing methodology as that of bioretention basins**.

The elevation of the overflow structure should be 1.0 feet above the elevation of the bioretention bed.

The **Runoff Pretreatment, Drainage Considerations**, and **Exclusion of Continuous Flows and Chlorinated Flows** considerations of **MINIMUM STANDARD 3.11: BIORETENTION BASINS**, are also applicable to bioretention filters. If the filter soil remains constantly wet, anaerobic conditions will develop, which will kill the plants and cause iron phosphates which have been previously captured to break down and escape into the effluent.

Continuous or frequent flows (such as basement sump pump discharges, cooling water, condensate water, artesian wells, etc.) and flows containing swimming pool and sauna chemicals must be EXCLUDED from routing through bioretention or bioretention filter BMPs since such flows will cause the BMP to MALFUNCTION!

The **Planting Plan, Planting Soil Guidelines, Mulch Layer Guidelines, Plant Material Guidelines, Plant Growth and Soil Fertility** criteria of **MINIMUM STANDARD 3.11: BIORETENTION BASINS**, also apply to bioretention filters.

<u>Basin Liners</u>

Impermeable liners may be either clay, concrete or geomembrane. If geomembrane is used, suitable geotextile fabric shall be placed below and on the top of the membrane for puncture protection. Clay liners shall meet the specifications in **Table 3.11A-2**.

The clay liner shall have a minimum thickness of 12 inches.

If a geomembrane liner is used it shall have a minimum thickness of 30 mils and be ultraviolet resistant.

The geotextile fabric (for protection of geomembrane) shall meet the specifications in **Table 3.11A-3**.

TABLE 3.11A - 2
Clay Liner Specifications (Source: City of Austin)

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	Cm/Sec	1×10^{-6}
Plasticity Index of Clay	ASTM D-423 & D-424	%	Not less than 15
Liquid Limits of Clay	ASTM D-2216	%	Not less than 30
Clay Compaction	ASTM-2216	%	95% of Standard Proctor Density
Clay Particles Passing	ASTM D-422	%	Not less than 30

TABLE 3.11A - 3
Geotextile Specification for Basin Liner "Sandwich"

Property	Test Method	Unit	Specification
Unit Weight		Oz./Sq.Yd.	8 (minimum)
Filtration Rate		In./Sec.	0.08 (minimum)
Puncture Strength	ASTM D-751 (Modified)	Lb.	125 (minimum)
Mullen Burst Strength	ASTM D-751	Psi.	400 (minimum)
Tensile Strength	ASTM D-1682	Lb.	300
Equiv. Opening Size	U.S. Standard Sieve	No.	80 (minimum)

Source: City of Austin

Equivalent methods for protection of the geomembrane liner will be considered on a case by case basis. Equivalency will be judged on the basis of ability to protect the geomembrane from puncture, tearing and abrasion.

When molded chambers are incorporated into the design, a minimum of four inches of gravel or crushed stone should be added beneath the molded chambers or other conveyance system to allow settling of filter fines into the voids. As with bioretention basins, filter strips, grassed channels, and side slopes should be sodded with mature sod, and planting soil should be wrapped up the side slopes under the sod.

All other factors dealing with bioretention filters are identical to those for bioretention basins in general, **M.S.3.11.**

MINIMUM STANDARD 3.11B

GREEN ALLEYS

Definition

Green Alleys consist of a network of bioretention basins/infiltration trenches or bioretention filters that provide both redundant water quality management and stormwater conveyance to stormwater management facilities. They create a carefully landscaped green border along, or a dividing corridor through, a development site. Unless otherwise noted, the information on Green Alleys in this section was provided by Keith Bowers of Biohabitats, Inc.

Green Alleys combine the redundancy of multiple stormwater quality BMPs and stormwater conveyance with urban and suburban site design features. Using bioretention, infiltration, and filtration as a foundation, Green Alleys consist of an above ground and below ground green ribbon of interconnecting BMPs that treat the first flush of stormwater while conveying excess runoff to management facilities. While Green Alleys provide an ecosystem based stormwater management technique, they also connect and facilitate the awareness of natural ecologic and hydrologic cycles.

Above ground, Green Alleys consist of a strip (greenway) consisting of native trees, schrubs, and groundcover that replicates native forest ecosystems and landscape processes to enhance sormwater quality. Green Alleys can also consist of a mixture of hardscape and landscape incorporating such features as walkways, urban plazas, open spaces, and streetscapes. Below ground, Green Alleys consist of sand filters and infiltration trenches that are connected by a series of perforated and solid pipes or molded plastic infiltration galleries that convey excess stormwater to quantity management facilities.

Purpose

Like bioretention basins and bioretention filters, green alleys are used primarily for water quality control. A number of other benefits may also accrue from green alleys. They provide redundancy in the number of treatment techniques and, except where precluded by soil conditions, some opportunity for infiltration even where filters are used; they may reinforce the visual and physical connection between the urban environment and the surrounding natural features; they may provide a greenway corridor (hedgerow) for wildlife habitat and/or pedestrian circulation; they may provide a green buffer between different land uses; and the system continues to function even if individual parts fail.

Water Quality Enhancement

As with other bioretention facilities, the treatment volume is managed and treated through microbial action and soil chemestry (nutrient cycling), evaportransporation, adsorption, and, where applicable, soîl infiltration. The manner in which these processes work is discussed under **MINIMUM STANDARD 3.11, BIOTETENTION BASINS**. **Table 3.11B-1** provides pollutant removal efficiencies for Green Alleys based on the volume of water to be treated.

TABLE 3.11B - 1
Pollutant Removal Efficiencies for Green Alleys

BMP Description	Target Pollutant Removal Efficiency (Phosphorous)
Green Alleys with capture and treatment volume equal to 0.5 inches of runoff from the impervious area.	50%
Green Alleys with capture and treatment volume equal to 1.0 inches of runoff from the impervious area.	65%

Flood Control and Channel Erosion Control

The amount of flood and channel erosion control provided by Green Alleys depends on the local rainfall frequency spectrum, the amount of pre-development (or pre-redevelopment) impervious cover, the amount of post-development impervious cover, and the volume of runoff captured and infiltered by the basin(s). The effect of the BMPs on peak flow rates from the drainage shed must be examined. As with other infiltration practices, bioretention basins tend to reverse the consequences of urban development by reducing peak flow rates and providing groundwater discharge.

Conditions Where Practice Applies

Green Alleys are generally suited for almost all types of development, from single-family residential to fairly high density commercial projects. They are attractive for higher density projects because of their relatively high removal eccifiency. The critical prerequisite is the existence of a deep enough storm sewer to accept drainage from the collector pipe system by gravity flow. All of the applications shown in **Figures 3.11-2** through **3.11-6** under **MS 3.11** may be built as bioretention filters.

Planning Considerations

Stormwater Management Concept Plan

Like all bioretention facilities, Green Alleys must be planned within the context of an overall stormwater management concept plan which addresses potential flooding and streambank erosion protection as well as water quality. This concept plan must be developed very early in the planning process to assure that sufficient space in the proper hydrological and hydraulic locations is reserved for stormwater management facilities. Minimum information necessary to develop a stormwater concept plan includes: existing and proposed drainage areas, size and capacity of downstream drainage conveyances, soils stidies, existing vegetation, and hydrographic features such as streams, floodplains, and wetlands, boundaries of Chesapeake Bay Preservation Resource Protection Areas. The plan must address the proposed location of areas of impervious cover on the site, the methods for collection and conveyance of runoff to an adequate channel or conduit, proposed detention facilities to address streambank erosion and potential flooding, and the proposed methods of providing quality treatment of the runoff.

Site Conditions

The **Site Conditions** considerations for for bioretention basins contained in **MINIMUM STANDARD 3.11: BIORETENTION BASINS** and **MS 3.11A: Bioretention Filters**, apply to Green Alleys which employ these BMPs. The same drainage area range applies, as do the same **Location Considerations.** In addition to site conditions, the following apply specifically to bioretention basins.

All other considerations for **M.S. 3.11, Bioretention Basins**, apply to Green Allies.

Chapter 3.11

Bioretention Filter in ultra-surban setting. Note curb cut, gravel energy dissipater, and clean out/observation wells.

Bioretention Filter located in required parking lot green space.

Bioretention Basin Practices

Chapter 3.11

Bioretention Filter in multi-family residential setting.

Bioretention Basins in office setting parking lot.

Bioretention Basin Practices